

Gulf Cooperation Council

EDICT OF GOVERNMENT

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GSO 221 (1994) (English): INDUSTRIAL SAFETY AND
HEALTH REGULATIONS PARTS 9, 10, 11, 12, 13, 14
BUILDING AND CONSTRUCTION



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STANDARDIZATION ORGANIZATION FOR G.C.C (GSO)



GSO 221/1994

اشتراطات السلامة والصحة الصناعية
الاجزاء أرقام 9 ، 10 ، 11 ، 12 ، 13 ، 14
أعمال الانشاء والبناء

INDUSTRIAL SAFETY AND HEALTH REGULATIONS
PARTS 9, 10, 11, 12, 13, 14
BUILDING AND CONSTRUCTION

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**INDUSTRIAL SAFETY AND HEALTH REGULATIONS
PARTS 9, 10, 11, 12, 13, 14
BUILDING AND CONSTRUCTION**

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INTRODUCTION

This standard forms a part of the Gulf Industrial Safety and Health Regulations. it is complementary to the other parts, of which a complete list can be found in GSO 1580/2002 “Industrial Safety and Health Regulations, Part 1, List of Contents” which can be obtained from the Saudi Arabian Standards Organization.

1. SCOPE

This standard is concerned with Industrial Safety and Health Regulations, Parts 9, 10, 11, 12, 13, and 14 – Building and Construction.

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INDUSTRIAL SAFETY AND HEALTH REGULATIONS**PARTS 9, 10, 11, 12, 13, 14****BUILDING AND CONSTRUCTION****9. EXCAVATIONS, TRENCHING, AND SHORING****9.1 Definitions**

Adit. A nearly horizontal passage from the surface into a mine.

Angle of Repose. The greatest angle above the horizontal plane at which a material will lie without sliding.

Bank. A mass of soil rising above a digging level.

Belled Excavation. An enlargement of the cross section of a shaft or footing excavation, usually near the bottom and bell-shaped.

Braces (Trench). The horizontal members of the shoring system whose ends bear against the uprights or stringers.

Cofferdam. A watertight enclosure, as of piles packed with clay, from which the water is pumped to expose the bottom (of a river, or other body of water) and permit the laying of foundations, building of piers, or other construction operations.

Cribbing. Cellular frameworks assembled in layers at right angles used in construction of foundations, dams, retaining walls.

Excavation. Any manmade cavity or depression in the earth's surface, including its sides, walls, or faces, formed by earth removal and producing unsupported earth conditions by reasons of the excavation. If installed forms or similar structures reduce the depth-to-width relationship, an excavation may become a trench.

Grabbing. A mechanical device for gripping objects.

Hard Compact Soil. All earth materials not classified as running or unstable.

Kickouts. Accidental release or failure of a shore or brace.

Muck Bucket. Bucket used in excavation of ore or rock in loose heap, as first broken, also burden, in hydraulic mining.

Sheeting. A lining of planks or boards for supporting an embankment or excavation face, usually placed vertically and supported by horizontal stringers which are in turn supported by braces or piles.

Sheet Pile. A pile, or sheeting, that may form one of a continuous interlocking line, driven in close contact to provide a tight wall to resist the lateral pressure of water, adjacent earth, or other materials.

Sides, Walls, or Faces. The vertical or inclined earth surface formed as a result of excavation work.

Sliding Tunnel Shields. An iron or steel framework moved forward at the end of a tunnel or adit in process of excavation to support the ground ahead of the concrete, cast iron, brickwork, or other lining.

Slope. The angle of an incline with the horizontal.

Stringers. The horizontal members of a shoring system whose sides bear against the uprights sheeting or earth.

Trench. A narrow excavation made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench is not greater than 4.5 m.

Trench Boxes. A portable rectangular shoring used for protecting workman in a trench.

Trench Jack. Screw or hydraulic type jacks used as cross bracing in a trench shoring system.

Trench Shield. A shoring system composed of steel plates and bracing, welded or bolted together, which support the walls of a trench from the ground level to the trench bottom and which can be moved along as work progresses.

Unstable Soil. Earth material, other than running, that because of its nature or the influence of related conditions, cannot be depended upon to remain in place without extra support, such as would be furnished by a system of shoring.

Uprights. The vertical members of a shoring system.

9.2 General

- 9.2.1 Walkways, runways, and sidewalks shall be kept clear of excavated material or other obstructions and no sidewalks shall be undermined unless shored to carry a minimum live load of 0.6 kg/sq cm.
- 9.2.2 If planks are used for raised walkways, runways, or sidewalks, they shall be laid parallel to the length of the walk and fastened together against displacement.
- 9.2.3 Planks shall be uniform in thickness and all exposed ends shall be provided with beveled cleats to prevent tripping.
- 9.2.4 Raised walkways, runways, and sidewalks shall be provided with plank steps on strong stringers. Ramps, used in lieu of steps, shall be provided with cleats to insure a safe walking surface when slope is greater than 10 degrees. Ramps greater than 20 degrees shall not be permitted.
- 9.2.5 Employees exposed to vehicular traffic shall be provided with and shall be instructed to wear warning vests marked with or made of reflectorized or highly visible material.
- 9.2.6 Employees subjected to hazardous dusts, gases, fumes, mists, or atmospheres deficient in oxygen, shall be protected with approved respiratory protection. (Ref. Section 5.3).
- 9.2.7 No person shall be permitted under loads handled by power shovels, derricks, or hoists.

- 9.2.8 To avoid injury from spillage, employees shall be required to stand away from any vehicle being loaded.
- 9.2.9 Daily inspection of excavations shall be made by a competent person. If evidence of possible cave-ins or slides is apparent, all work in the excavation shall cease until the necessary precautions have been taken to safeguard the employees.
- 9.2.10 Convenient and safe means shall be provided for workmen to enter and leave the excavated area. This shall consist of a standard stairway, ladder or ramp securely fastened in place at suitably guarded or protected locations.
- 9.2.11 At least two means of exit shall be provided. Where the width of the excavation exceeds 30 m, 2 or more means of exit shall be provided on each side of the excavation.
- 9.2.12 Where employees or equipment are required or permitted to cross over excavations, walkways or bridges with standard guardrails shall be provided.
- 9.3 Excavation Requirements**
- 9.3.1 Prior to opening an excavation, the location of underground installations such as: sewer, telephone, water, fuel, and electric lines shall be determined.
- 9.3.2 When the excavation approaches the estimated location of an underground installation, the exact location shall be determined by careful probing or hand digging 3 m each side of installation.
- 9.3.3 When uncovered, the underground installation shall be provided proper protection and supports to prevent any damage.
- 9.3.4 Utility companies shall be contacted and advised of proposed work prior to the start of actual excavation.
- 9.3.5 Trees, boulders, and other surface encumbrances, located so as to create a hazard to employees involved in excavation work or in the vicinity, thereof at any time during operations, shall be removed or made safe before excavating is begun.
- 9.3.6 The walls and faces of all excavations in which employees are exposed to danger from moving ground shall be guarded by a shoring system, laid back on a stable slope, or some other equivalent means.
- 9.3.7 Excavations shall be inspected by a competent person after every rainstorm or other hazard increasing occurrence. Protection against slides and cave-ins shall be increased if necessary.
- 9.3.8 The determination of the angle of repose and design of the supporting system shall be based on careful evaluation of pertinent factors such as: soil or rock properties; depth of cut; possible variation in water content of the material while the excavation is open; anticipated changes in materials from exposure to air, sun, water, or freezing; loading imposed by structures, equipment, overlying materials, or stored materials; and vibration from equipment, blasting, traffic, or other sources.
- 9.3.9 Supporting systems using piling, cribbing, shoring, etc., shall be designed by a qualified person and meet good engineering practice.

- 9.3.10 When tie rods are used to restrain the top of sheeting or other retaining systems, the rods shall be securely anchored well back of the angle of repose.
- 9.3.11 When tight sheeting or sheet piling is used, full loading due to ground water table shall be assumed, unless prevented by weep holes or drains or other means. Additional stringers, ties, and bracing shall be provided to allow for any necessary temporary removal of individual supports.
- 9.3.12 All slopes shall be excavated to at least the angle of repose except for areas in solid rock.
- 9.3.13 The angle of repose shall be flattened when an excavation has water conditions, silty materials, loose boulders, and areas where erosion, deep frost action, and slide planes appear.
- 9.3.14 In excavations which employees may be required to enter, excavated or other materials shall be effectively stored and retained at least 1 m or more from the edge of the excavation.
- 9.3.15 Sides, slopes, and faces of all excavations shall meet good engineering practice by scaling, benching, barricading, rock bolting, wire meshing, or other equally effective means. Special attention shall be given to slopes which may be adversely affected by weather or moisture content.
- 9.3.16 Support systems shall be planned and designed by a qualified person when excavation is in excess of 7 m in depth, adjacent to structures or improvements, or subject to vibration or ground water.
- 9.3.17 Materials used for sheeting, sheet piling, cribbing, bracing, shoring, and underpinning shall be in good serviceable condition. Timbers shall be sound, free from large or loose knots, and of proper dimensions.
- 9.3.18 Special precautions shall be taken in sloping or shoring the sides of excavations adjacent to a previously back filled excavation or a fill, particularly when the separation is less than the depth of the excavation. Particular attention also shall be paid to joints and seams in the face and the slope of such excavations or fills.
- 9.3.19 Except in hard rock, excavations below the level of the base of footing of any foundation or retaining wall shall not be permitted, unless the wall is underpinned and all other precautions taken to insure the stability of the adjacent walls for the protection of employees involved in excavation work or in the vicinity thereof.
- 9.3.20 If the stability of adjoining buildings or walls is endangered by excavations, shoring, bracing, or underpinning shall be provided as necessary to ensure their safety. Such shoring, bracing, or underpinning shall be inspected daily or more often, as conditions warrant, by a competent person and the protection effectively maintained.
- 9.3.21 Diversion ditches, dikes, or other suitable means shall be used to prevent surface water from entering an excavation and to provide adequate drainage of the area adjacent to the excavation. Water shall not be allowed to accumulate in an excavation.
- 9.3.22 If it is necessary to place or operate power shovels, derricks, trucks, materials, or other heavy objects on a level above and near an excavation, the side of the

excavation shall be sheet piled, shored, and braced as necessary to resist the extra pressure due to such superimposed loads.

- 9.3.23 When mobile equipment is utilized or allowed adjacent to excavations, substantial stop logs or barricades shall be installed. If possible the grades should slope away from the excavation.
- 9.3.24 Adequate barrier physical protection shall be provided at all remotely located excavations. All wells, pits, shafts, etc., shall be barricaded or covered. Upon completion of exploration and similar operations, temporary wells, shafts, etc. shall be back filled.
- 9.2.25 Dust conditions shall be kept to a minimum by the use of water, calcium chloride, oil, or other means.
- 9.3.26 In locations where oxygen deficiency or gaseous conditions are possible, air in the excavation shall be tested by a competent person. Controls shall be established to assure acceptable atmospheric conditions for respirable air. When flammable gases are present, ventilation shall be provided and sources of ignition eliminated. Emergency rescue equipment, such as breathing apparatus, safety harness with lines, shall be readily available when adverse breathing conditions may exist or develop in an excavation.
- 9.3.27 Where ramps are used for employees or equipment, they shall be designed and constructed by qualified persons in accordance with good engineering practices.

9.4 Trenching Requirements

- 9.4.1 Banks of all trenches more than 1.5 m high shall be shored, laid back to a stable slope, or some other equivalent means of protection shall be provided where employees may be exposed to moving ground or cave-ins. Refer to Figure 9.4-1 as a guide in determining the sloping of banks depending upon the nature of the ground. Trenches less than 1.5 m in depth shall also be effectively protected when examination indicates hazardous ground movement may be expected.
- 9.4.2 Sides of trenches in unstable or soft material, 1.5 m or more in depth, shall be shored, sheeted, braced, sloped, or otherwise supported by means of sufficient strength to protect employees working within them. See Figure 9.4-1 and Table 9.4-1.
- 9.4.3 In trenches which employees may be required to enter, excavated or other material shall be effectively stored and retained at least 1 m or more from the edge of the trench.
- 9.4.4 Sides of trenches in hard or compact soil, including embankments, shall be shored or otherwise supported when the trench is more than 1.5 m in depth and 2.5 m or more in length. In lieu of shoring, the sides of the trench above the 1.5 m level may be sloped to preclude collapse, but shall not be steeper than a 1 to 1/2 slope ratio. When the outside diameter of a pipe placed in the trench is greater than 1.8 m, a bench of 1 m minimum shall be provided at the toe of the sloped portion.
- 9.4.5 Materials used for sheeting and sheet piling, bracing, shoring, and underpinning, shall be in good serviceable condition. Timbers used shall be sound and free from

large or loose knots, and shall be designed and installed so as to be effective to the bottom of the excavation.

- 9.4.6 Additional precautions by way of shoring and bracing shall be taken to prevent slides or cave-ins when excavations or trenches are made in locations adjacent to back filled excavations, or where excavations and trenches are subjected to vibrations from railroad or highway traffic, the operation of machinery, or any other source.
- 9.4.7 Minimum requirements for trench timbering shall be in accordance with Table 9.4-1.
- 9.4.8 Braces and diagonal shores in a wood shoring system shall not be subjected to compressive stress in excess of values given by the following formula:

$$S = 90 - \frac{1.4L}{D}$$

$$\text{Maximum rating} \quad \frac{L}{D} = 50$$

Where:

L = Length, unsupported, in cm

D = Least side of the timber in cm

S = Allowable stress in kg/sq cm

- 9.4.9 When employees are required to be in trenches 1.2 m deep or more, adequate means of exit, such as a ladder or steps, shall be provided and located so as to require no more than 7.5 m of lateral travel.
- 9.4.10 Bracing or shoring of trenches shall be carried along with the excavation.
- 9.4.11 Cross braces or trench jacks shall be placed in true horizontal position, be spaced vertically, and be secured to prevent sliding, failing, or kickouts.
- 9.4.12 Portable trench boxes or sliding trench shields may be used for the protection of personnel in lieu of a shoring system or sloping. Where trench boxes or shields are used they shall be designed, constructed and maintained in a manner which will provide protection equal to or greater than the sheeting or shoring required for the trench.
- 9.4.13 Backfilling and removal of trench supports shall progress together from the bottom of the trench. Jacks or braces shall be released slowly and, in unstable soil, ropes shall be used to pull out the jacks or braces from above after employees have cleared the trench.

**Approximate angle for repose for sloping of
sides of excavations**

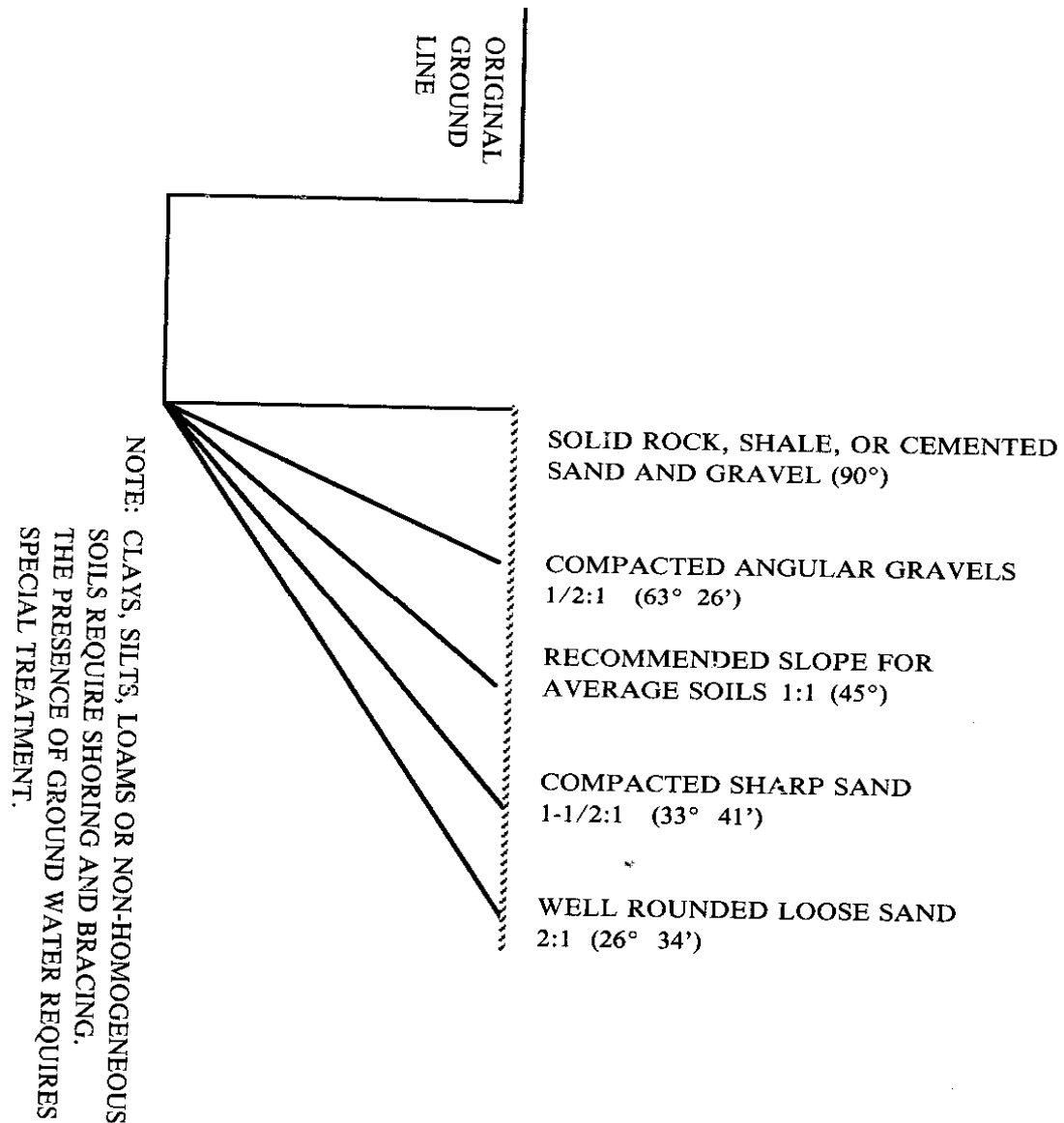


Figure 9.4-1

Table 9.4-1
Trench Shoring - Minimum Requirements

Depth of Trench (m)	Kind or Condition of Earth	Size and Spacing of Members			
		Uprights		Stringers (2)	
		Minimum Dimension (mm)	Maximum Spacing (m)	Minimum Dimension (mm)	Cross Braces (1) Width of Trench (m) Up to .9 1.8 1.8 to 2.7 2.7 to 3.6 3.6 to 4.5
1.5 to 3	Hard, compact	80 x 100 or 50 x 160	1.8	-----	50 x 160 100 x 100 100 x 160 160 x 160 160 x 200
	Likely to crack	80 x 100 or 50 x 160	1	100 x 160	50 x 160 100 x 100 100 x 160 160 x 160 160 x 200
	Soft, sandy, of filled	80 x 100 or 50 x 160	Close sheeting	100 x 160	100 x 100 100 x 160 160 x 160 160 x 200 200 x 200
	Hydrostatic pressure	80 x 100 or 50 x 160	Close sheeting	160 x 200	100 x 100 100 x 160 160 x 160 160 x 200 200 x 200
3 to 4.5	Hard	80 x 100 or 50 x 160	1.2	100 x 160	100 x 100 100 x 160 160 x 160 160 x 200 200 x 200
	Likely to crack	80 x 100 or 50 x 160	.6	100 x 160	100 x 100 100 x 160 160 x 160 160 x 200 200 x 200
4.6 to 6	Soft, sandy or filled	80 x 100 or 50 x 160	Close sheeting	100 x 160	100 x 160 160 x 160 160 x 200 200 x 200 200 x 260
	Hydrostatic pressure	80 x 160	Close sheeting	100 x 160	100 x 160 160 x 160 160 x 200 200 x 200 200 x 260
Over 6	All kinds or conditions	80 x 160	Close sheeting	100 x 300	100 x 300 160 x 200 200 x 200 200 x 260 260 x 260
	All kinds or conditions	80 x 160	Close sheeting	100 x 300	100 x 300 200 x 200 200 x 260 260 x 260 260 x 300

(1) Trench jacks may be used in lieu of, or in combination with, cross braces. Shoring is not required in solid rock, hard shale, or hard slag.

Steel sheet piling and bracing of equal strength may be substituted for wood. Maximum spacing of cross braces = 1.2 m vertical - 1.8 m horizontal.

(2) Maximum spacing of stringers = 1.2 m.

10. CONCRETE WORK

10.1 Definitions

Bull Float. A tool used to spread out and smooth the concrete.

Formwork or Falsework. The total system of support for freshly placed concrete, including the mold or sheathing which contacts the concrete as well as all supporting members, hardware, and necessary bracing.

Guy. A line that steadies a high piece or structure by pulling against an off-center load.

Pumpcrete. Concrete conveyed through a pipeline or hose by the mechanical force exerted by a piston under pneumatic pressure, or a roller acting on the material.

Shore. A supporting member that resists a compressive force imposed by a load.

Vertical Slip Forms. Forms which are jacked vertically and continuously during placing of the concrete.

10.2 Reinforcing Steel

10.2.1 Employees working more than 2 m above any adjacent working surface, placing and tying reinforcing steel in walls, piers, columns, etc., shall be provided with and required to use a safety belt or equivalent device in accordance with Section 5.8.

10.2.2 Employees shall not be permitted to work above vertically protruding reinforcing steel unless it has been protected to eliminate the hazard of impalement.

10.2.3 Reinforcing steel for walls, piers, columns and similar vertical structures shall be guyed and supported to prevent collapse.

10.2.4 Wire mesh rolls shall be secured at each end to prevent dangerous recoiling action.

10.3 Concrete Placement

10.3.1 Concrete mixtures equipped with 1 cu m or larger loading skips shall be equipped with a mechanical device to clear the skip of material.

10.3.2 Mixers of 1 cu m capacity or greater shall be equipped with protective guardrails installed on each side of the skip.

10.3.3 Handles on bull floats, used where the handles may contact energized electrical conductors, shall be constructed of nonconductive material, or insulated with a nonconductive sheath whose electrical and mechanical characteristics provide the equivalent protection of handle constructed of nonconductive material.

10.3.4 Powered and rotating-type concrete trowling machines that are manually guided shall be equipped with a control switch that will automatically shut off the power whenever the operator removes his hands from the equipment handles.

10.3.5 Installation of guards on buggy handles to protect hand knuckles is required.

10.3.6 Pumpcrete or similar systems using discharge pipes shall be provided with pipe supports designed for 100 percent overload. Compressed air hose in such systems

shall be provided with positive failsafe joint connectors to prevent separation of sections when pressurized.

- 10.3.7 Concrete buckets equipped with hydraulic or pneumatically operated gates shall have positive safety latches or similar safety devices installed to prevent aggregate and loose material from accumulating on the top and sides of the bucket.
- 10.3.8 Riding of concrete buckets for any purpose shall be prohibited, and vibrator crews shall be kept out from under concrete buckets suspended from cranes or cableways.
- 10.3.9 When discharging on a slope, the wheels of ready-mix trucks shall be blocked and the brakes set to prevent movement.
- 10.3.10 Nozzlemen applying a cement, sand, and water mixture through a pneumatic hose shall be required to wear protective head and face equipment, as Prescribed in Section 5.0.

10.4 Vertical Shoring

10.4.1 General Requirements

- 10.4.1.1 All formwork including shoring and bracing shall be designed by a structural engineer.
- 10.4.1.2 When temporary storage of reinforcing rods, material, or equipment on top of formwork becomes necessary, these areas shall be strengthened to meet the intended loads.
- 10.4.1.3 The sills for shoring shall be sound, rigid, and capable of carrying the maximum intended load.
- 10.4.1.4 All shoring equipment shall be inspected prior to erection to determine that it is as specified in the shoring layout. Any equipment found to be damaged shall not be used for shoring.
- 10.4.1.5 Erected shoring equipment shall be inspected immediately prior to, during, and immediately after the placement of concrete. Any shoring equipment that is found to be damaged or weakened shall be immediately reinforced or reshored.
- 10.4.1.6 Reshoring shall be provided when necessary to safely support slabs and beams after stripping, or where such members are subjected to superimposed loads due to construction work done.

10.4.2 Tubular Welded Frame Shoring

- 10.4.2.1 Metal tubular frames used for shoring shall not be loaded beyond the safe working load recommended by the manufacturer.
- 10.4.2.2 All locking devices on frames and braces shall be in good working order; coupling pins shall align the frame or panel legs; pivoted cross braces shall have their center pivot in place; and all components shall be in a condition similar to that of original manufacture.
- 10.4.2.3 When checking the erected shoring frames with the shoring layout, the spacing between towers and cross brace spacing shall not exceed that shown on the layout, and all locking devices shall be in the closed position.

- 10.4.2.4 Devices for attaching the external lateral stability bracing shall be securely fastened to the legs of the shoring frames.
- 10.4.2.5 All baseplates, shore heads, extension devices, or adjustment screws shall be in firm contact with the footing sill and the form.
- 10.5 **Forms and Shoring**
 - 10.5.1 Formwork and shoring shall be designed, erected, supported, braced, and maintained so that it will safely support all vertical and lateral loads that may be imposed upon it during placement of concrete.
 - 10.5.2 Drawings or plans showing the jack layout, formwork, shoring, working decks, and scaffolding, shall be available at the jobsite.
 - 10.5.3 Stripped forms and shoring shall be removed and stockpiled promptly after stripping in all areas in which persons are required to work or pass. Protruding nails, wire ties, and other form accessories not necessary to subsequent work shall be pulled, cut, or other means taken to eliminate the hazard.
 - 10.5.4 Imposition of any construction loads on the partially completed structure shall not be permitted unless such loading has been considered in the design and approved by the engineer-architect.
 - 10.5.5 Vertical Slip Forms
 - 10.5.5.1 The steel rods or pipe on which the jacks climb or by which the forms are lifted shall be specifically designed for the purpose. Such rods shall be adequately braced where not encased in concrete.
 - 10.5.5.2 Jacks and vertical supports shall be positioned in such a manner that the vertical loads are distributed equally and do not exceed the capacity of the jacks.
 - 10.5.5.3 The jacks or other lifting devices shall be provided with mechanical dogs or other automatic holding devices to provide protection in case of failure of the power supply or the lifting mechanism.
 - 10.5.5.4 Lifting shall proceed steadily and uniformly and shall not exceed the predetermined safe rate of lift.
 - 10.5.5.5 Lateral and diagonal bracing of the forms shall be provided to prevent excessive distortion of the structure during the jacking operation.
 - 10.5.5.6 During jacking operations, the form structure shall be maintained in horizontal and vertical alignment.
 - 10.5.5.7 All vertical lift forms shall be provided with scaffolding or work platforms completely encircling the area of form placement.
 - 10.5.6 Tube and Coupler Shoring
 - 10.5.6.1 Couplers (clamps) shall not be used if they are deformed, broken, or have defective or missing threads on bolts, or other defects.
 - 10.5.6.2 The material used for the couplers shall be of a structural type such as drop-forged steel, malleable iron, or structural grade aluminium. Gray cast iron shall not be used.

- 10.5.6.3 When checking the erected shoring towers with the shoring layout, the spacing between posts shall not exceed that shown on the layout, and all interlocking of tubular members and tightness of couplers shall be checked.
- 10.5.6.4 All baseplates, shore heads, extension devices, or adjustment screws shall be in firm contact with the footing sill and the form material and shall be snug against the posts.
- 10.5.7 Single Post Shores
- 10.5.7.1 For stability, single post shores shall be horizontally braced in both the longitudinal and transverse directions, and diagonal bracing shall also be installed. Such bracing shall be installed as the shores are being erected.
- 10.5.7.2 All baseplates or shore heads of single post shores shall be in firm contact with the footing sill and the form materials.
- 10.5.7.3 Whenever single post shores are used in more than 1 tier, the layout shall be designed and inspected by a structural engineer.
- 10.5.7.4 When framework is at an angle, or sloping, or when the surface shored is sloping, the shoring shall be designed for such loading.
- 10.5.7.5 Adjustment of single post shores to raise formwork shall not be made after concrete is in place.
- 10.5.7.6 Fabricated single post shores shall not be used if heavily rusted, bent dented, rewelded, or have broken weldments or other defects.
- 10.5.7.7 All timber and adjusting devices to be used for adjustable timber single post shores shall be inspected before erection.
- 10.5.7.8 Timber shall not be used if it is split. cut, has sections removed, is rotted, or is otherwise structurally damaged.
- 10.5.7.9 Adjusting devices shall not be used if heavily rusted, bent, dented, rewelded or have broken weldments or other defects.
- 10.5.7.10 All nails used to secure bracing and adjustable timer single post shores shall be driven full depth and the point of the nail bent over if possible.
- 10.6 **Precast Concrete Construction, Including Tilt-Up**
- 10.6.1 The lifting attachments in precast concrete shall provide sufficient strength and be properly designed by a structural engineer for the expected loads, including impact.
- 10.6.2 Bent bars of concrete reinforcing steel shall not be used as lifting attachments if the load to be imposed on any such attachment will exceed 900 kg. Concrete reinforcing steel to be used in this manner shall be of such size and design that the factor of safety will be at least 10. The radii of all bends shall not be less than 6 times the bar diameter.
- 10.6.3 When precast walls or vertical panels are erected, the bracing must be designed and installed to withstand a wind load of at least 50 kg/sq m. Braces or shores used for this purpose must have positive attachments at each end that do not rely

on slotted or similar clips of a type that might become disengaged from a lateral force on the shore.

- 10.6.4 Concrete panels, slabs, or other structural members shall have lifting surfaces clean, well bonded, and monolithic before vacuum lifting is attempted.

10.7 Lift-Slab Operations

- 10.7.1 The building, columns and related structural elements shall be adequate, according to recognized engineering formula and standards, to resist without undue deflection all vertical and lateral loads to which they will be subjected during and after slab-lifting operations.
- 10.7.2 Each lift-slab project shall be planned in advance to determine whether or not temporary support or bracing is required during the erection stage. Conclusions reached shall be justified by calculations and described by sketches or written instructions approved by an engineer or architect, with previous experience. The approved sketches and/or instructions shall be adequate to describe all necessary safeguards, and shall be available at the site during and for 1 week prior to lift-slab operations.
- 10.7.3 Jacking equipment shall not be loaded beyond safe working capacity, and the threaded rods or other members that transmit loads to the jacks shall have a factor of safety of at least 2.5.
- 10.7.4 Jacks shall be designed or equipped so that they will not continue to lift when overloaded. In the case of hydraulic or air-operated jacks, this may be accomplished by regulators that limit the magnitude of operating pressure delivered to the jacks.
- 10.7.5 A safety device shall be provided on each jack so that it will continue to support its load in a raised position, even if a failure should destroy or interfere with its jacking ability.
- 10.7.6 Jack operation shall be synchronized so that the slab is lifted evenly, with an elevation at all points of support within 13 mm of that needed to maintain a level slab. If this is accomplished with automatic controls, such controls shall be of a fail-safe type that will stop the whole operation in the event of a failure that interferes with proper functioning of any important part.
- 10.7.7 If the proper level is maintained by manual controls, such controls shall be at a central location, with a trained operator in attendance where lifting is in progress.
- 10.7.8 The maximum number of manually controlled jacks operating on 1 slab shall be limited to 14, and shall never be so numerous that the operator fails to keep the slab level, within specified limits.
- 10.7.9 There shall be a control for each jack and indicators that continuously register the relative elevations at each pick-up point.

11. STEEL ERECTION

11.1 Definitions

Plumbing-Up. Alignment of vertical structural members to true vertical lines within tolerances.

11.2 **Flooring Requirements**

11.2.1 Permanent Flooring-Skeleton Steel Construction in Tiered Buildings

11.2.1.1 The permanent floors shall be installed as the erection of structural members progresses, and there shall be not more than 8 stories between the erection floor and the uppermost permanent floor, except where the structural integrity is maintained as a result of the design.

11.2.1.2 At no time shall there be more than 4 floors or 14.6 m of unfinished bolting or welding above the foundation or uppermost permanently secured floor.

11.2.1.3 Metal decking of sufficient strength shall be laid tightly and secured to prevent movement.

All unused openings in floors, temporary or permanent, shall be completely planked over and guarded in accordance with Section 2.5.

11.2.2 Temporary Flooring-Skeleton Steel Construction in Tiered Buildings

11.2.2.1 The erection floor shall be solidly planked or decked over its entire surface except for access openings. Planking or decking of equivalent strength, shall be of proper thickness to carry the working load. Planking shall be not less than 50 mm thick full size undressed, and shall be tight and secured to prevent movement.

11.2.2.2 On buildings or structures not adaptable to temporary floors, and where scaffolds are not used, safety nets shall be installed and maintained whenever the potential fall distance exceeds 2 stories or 7.6 m. The nets shall be hung with sufficient clearance to prevent contacts with the surface of structures below.

11.2.2.3 Floor periphery-safety railing. A safety railing of 10 mm minimum wire rope or equal shall be installed, approximately 1 m high, around the periphery of all temporary-planked or temporary metal-decked floors of tier buildings and other multifloored structures during structural steel assembly.

11.2.2.4 Where skeleton steel erection is being done, a tightly planked and substantial floor shall be maintained within 2 stories or 9.1 m, whichever is less, below and directly under that portion of each tier of beams on which any work is being performed, except when gathering and stacking temporary floor planks on a lower floor in preparation for transferring such plans for use on an upper floor. Where such a floor is not practicable, subparagraph 11.2.2.2 will apply.

11.2.2.5 When gathering and stacking temporary floor planks, the planks shall be removed successively, working toward the last panel of the temporary floor so that the work is always done from the planked floor.

11.2.2.6 When gathering and stacking temporary floor planks from the last panel, the employees assigned to such work shall be protected by safety belts with safety lines attached to a catenary line or other substantial anchorage.

11.2.2.7 Wood planking shall be of proper thickness to carry the working load but shall be not less than 50 mm thick full size undressed, exterior grade plywood at least 18 mm thick, or equivalent material.

- 11.2.2.8 Planks shall overlap the bearing on each end by a minimum of 30 cm.
- 11.2.2.9 Wire mesh, exterior plywood. or equivalent, shall be used around columns where planks do not fit tightly.
- 11.2.2.10 Provisions shall be made to secure temporary flooring against displacement.
- 11.2.3 **Flooring-Other Construction**
- 11.2.3.1 In the erection of a building having double wood floor construction, the rough flooring shall be completed as the building progresses, including the tier below the one on which floor joists are being installed.
- 11.2.3.2 For single wood floor or other flooring systems, the floor immediately below the story where the floor joists are being installed shall be kept planked or decked over.
- 11.3 **Structural Steel Assembly**
- 11.3.1 During the final placing of solid web structural members, the load shall not be released from the hoisting line until the members are secured with not less than 2 bolts, or the equivalent at each connection and drawn wrench tight.
- 11.3.2 Open web steel joists shall not be placed on any structural steel framework unless such framework is safely bolted or welded.
- 11.3.3 In steel framing, where bar joists are utilized, and columns are not framed in at least 2 directions with structural steel members, a bar joist shall be field-bolted at columns to provide lateral stability during construction.
- 11.3.4 Where longspan joists or trusses, 12.2 m or longer, are used a center row of bolted bridging shall be installed to provide lateral stability during construction prior to slacking of hoisting line.
- 11.3.5 No load shall be placed on open web steel joists until these security requirements are met.
- 11.3.6 Tag lines shall be used for controlling loads while being hoisted and connected.
- 11.4 **Bolting, Riveting, Fitting-Up, and Plumbing-Up**
- 11.4.1 **General**
- 11.4.1.1 Containers shall be provided for storing or carrying rivets, bolts, and drift pins, and secured to prevent falling when aloft.
- 11.4.1.2 Pneumatic hand tools shall be disconnected from the power source, and pressure in hose lines shall be released, before any adjustments or repairs are made.
- 11.4.1.3 Air line hose sections shall be safely coupled together except when quick disconnect couplers are used to join sections.
- 11.4.1.4 Eye protection shall be provided in accordance with Section 5.2.
- 11.4.2 **Bolting**
- 11.4.2.1 When bolts or drift pins are being knocked out. means shall be provided to keep them from falling.
- 11.4.2.2 Impact wrenches shall be provided with a locking device for retaining the socket.

- 11.4.3 Riveting
 - 11.4.3.1 Riveting shall not be done in the vicinity of combustible material unless precautions are taken to prevent fire.
 - 11.4.3.2 When rivet heads are knocked off, or backed out, means shall be provided to keep them from falling.
 - 11.4.3.3 A safety wire shall be properly installed on the snap and on the handle of the pneumatic riveting hammer and shall be used at all times.
- 11.4.4 Plumbing-Up
 - 11.4.4.1 Connections of the equipment used in plumbing-,up shall be properly secured.
 - 11.4.4.2 The turnbuckles shall be secured to prevent unwinding while under stress.
 - 11.4.4.3 Plumbing-up guys related to equipment shall be placed so that employees can get at the connection points.
 - 11.4.4.4 Plumbing-up guys shall be removed only under the supervision of a competent person.
 - 11.4.4.5 Employees shall use safety belts in accordance with Section 5.8 when they are working on float scaffolds (Ref. Section 6.9).

12. TUNNELS, SHAFTS, CAISSONS AND COFFERDAMS

12.1 Definitions

Adit. A nearly horizontal passage from the surface into a mine or other underground excavation.

Bulkhead. An airtight structure separating the working chamber from another chamber under a lesser pressure or from free air.

Caisson. A wood, steel, concrete or reinforced concrete, air and water-tight chamber in which it is possible for men to work under air pressure greater than atmospheric pressure to excavate material below water level.

Decanting. A method used for decompressing under emergency circumstances. In this procedure, the persons are brought to atmospheric pressure with a very high gas tension in the tissues and then immediately recompressed in a second and separate chamber or lock.

Emergency Locks. A lock designed to hold and permit the quick passage of an entire shift of employees.

Gauge Pressure (kg/sq cm g). Pressure measured by a gauge and indicating the pressure exceeding atmospheric.

High Air. Air pressure used to supply power to pneumatic tools and devices.

Jumbo. Portable carriage for attaching drills.

Lifter. Lowest row of drilled holes on face.

Low Air. Air supplied to pressurize working chambers and locks.

Man Lock. A chamber through which men pass from one air pressure environment into another.

Materials Lock. A chamber through which materials and equipment pass from one air pressure environment into another.

Medical Lock. A special chamber in which employees are treated for decompression illness. It may also be used in preemployment physical examinations to determine the adaptability of the prospective employee to changes in pressure.

Normal Condition. One during which exposure to compressed air is limited to a single continuous working period followed by a single decompression in any given 24-hour period; the total time of exposure to compressed air during the single continuous working period is not interrupted by exposure to normal atmospheric pressure, and a second exposure to compressed air does not occur until at least 12 consecutive hours of exposure to normal atmospheric pressure has elapsed.

Raise. An underground excavation advance in an upward direction.

Safety Screen. An air and water-tight diaphragm placed across the upper part of a compressed air tunnel between the face and bulkhead to prevent flooding the crown of the tunnel between the safety screen and the bulkhead, thus providing a safe means of refuge and exit from a flooding or flooded tunnel.

Scaling Bar. Metal bars used for "Scaling the roof or walls" to pry down any rock which might have been loosened by blasting.

Set. Structural members installed to support roof and walls of a tunnel.

Shaft. Vertical passageway between ground or water surface and box caissons.

Special Decompression Chamber. A chamber to provide greater comfort for employees when the total decompression time exceeds 75 min.

Working Chamber. The space or compartment under air pressure in which the work is being done.

12.2 **Compressed Air Environment**

12.2.1 **General**

12.2.1.1 There shall be present, at all times, at least one competent person designated by and representing the employer, who shall be familiar with this section in all respects, and responsible for full compliance with these and other applicable sections.

12.2.1.2 Every employee shall be instructed in the rules and regulations which concern his safety and the safety of others.

12.2.2 **Medical Attendance, Examination, and Regulations**

12.2.2.1 There shall be retained one or more licensed physicians familiar with and experienced in the physical requirements and the medical aspects of compressed air work and the treatment of decompression illness. He shall be available at all time while work is in progress in order to provide medical supervision of

employees employed in compressed air work. He shall himself be physically qualified and be willing to enter a pressurized environment.

- 12.2.2.2 No employee shall be permitted to enter a compressed air environment until he has been examined by the physician and reported by him to be physically qualified to engage in such work.
- 12.2.2.3 In the event an employee is absent from work for 10 days, or is absent due to sickness or injury, he shall not resume work until he is reexamined by the physician, and his physical condition reported to permit him to work in compressed air.
- 12.2.2.4 After an employee has been employed continuously in compressed air for a period designated by the physician, but not to exceed 1 year, he shall be reexamined by the physician to determine if he is still physically qualified to engage in compressed air work.
- 12.2.2.5 Such physician shall at all times keep a complete and full record of examinations made by him.
- 12.2.2.6 A fully equipped first aid station shall be provided at each tunnel project regardless of the number of persons employed. An ambulance or transportation suitable for a litter case shall be present at each project.
- 12.2.2.7 Where tunnels are being excavated from portals more than 8 km apart, a first aid station and transportation facilities shall be provided at each portal.
- 12.2.2.8 A medical lock shall be established and maintained in immediate working order whenever air pressure in the working chamber is increased above the normal atmosphere.
- 12.2.2.9 The medical lock shall:
- Have at least 1.8 m of clear headroom at the center, and be subdivided into not less than two compartments.
 - Be readily accessible to employees working in compressed air.
 - Be kept ready for immediate use for at least 5 hours subsequent to the emergence of any employee from the working chamber.
 - Be properly heated, lighted and ventilated.
 - Be maintained in a sanitary condition.
 - Have a nonshatterable port through which the occupant(s) may be kept under constant observation.
 - Be designed for a working pressure of 2.25 kg/sq cm g.
 - Be equipped with internal controls which may be overridden by external controls.
 - Be provided with air pressure gauges to show the air pressure within each compartment to observers inside and outside the medical lock.
 - Be equipped with a manual type sprinkler system that can be activated inside the lock or by the outside lock tender.

Be provided with oxygen lines and fittings leading into external tanks. The lines shall be fitted with check valves to prevent reverse flow. The oxygen system inside the chamber shall be of a closed circuit design and be so designed as to automatically shut off the oxygen supply whenever the fire system is activated.

Be in constant charge of an attendant under the direct control of the retained physician. The attendant shall be trained in the use of the lock and suitably instructed regarding steps to be taken in the treatment of employee exhibiting symptoms compatible with a diagnosis of decompression illness.

Be adjacent to an adequate emergency medical facility.

Have the medical facility equipped with demand-type oxygen inhalation equipment.

Be capable of being maintained at a temperature, in use, not to exceed 32°C nor be less than 21 degrees C.

Be provided with sources of air, free of oil and carbon monoxide, for normal and emergency use, which are capable of raising the air pressure in the lock from 0 to 2.25 kg/sq cm g in 5 min.

- 12.2.2.10 Identification badges shall be furnished to all employees, indicating that the wearer is a compressed air worker. A permanent record shall be kept of all identification badges issued. The badge shall give the employee's name, address of the medical lock, the telephone number of the licensed physician for the compressed air project, and contain instruction that in case of emergency of unknown or doubtful cause or illness, the wearer shall be rushed to the medical lock. The badge shall be worn at all times-off the job, as well as on the job.

- 12.2.3 Telephone and Signal Communication. Effective and reliable means of communication, such as bells, whistles, or telephones, shall be maintained at all times between all the following locations:

The working chamber face.

The working chamber side of the man lock near the door.

The interior of the man lock.

Lock attendant's station.

The compressor plant.

The first-aid station.

The emergency lock (if one is required).

The special decompression chamber (if one is required).

- 12.2.4 Signs and Records

- 12.2.4.1 The time of decompression shall be posted in each man lock as follows:

Time of Decompression for This Lock

----- kg to kg in ----- minutes.

----- kg to ----- kg in ----- minutes.

(Signed by) ----- (Superintendent)

This form shall be posted in the Man Lock at all times.

- 12.2.4.2 Any code of signals used shall be conspicuously posted near workplace entrances and such other locations as may be necessary to bring them to the attention of all employees concerned.
- 12.2.4.3 For each 8-hr. shift, a record of employees employed under air pressure shall be kept by an employee who shall remain outside the lock near the entrance. This record shall show the period each employee spends in the air chamber and the time taken from decompression. A copy shall be submitted to the appointed physician after each shift.
- 12.2.5 Compression
 - 12.2.5.1 Every employee going under air pressure for the first time shall be instructed on how to avoid excessive discomfort.
 - 12.2.5.2 During the compression of employees, the pressure shall not be increased to more than 0.21 kg/sq cm g, within the first minute. The pressure shall be held at 0.21 kg/sq cm g and against at 0.5 kg/sq cm g, sufficiently long to determine if any employees are experiencing discomfort.
 - 12.2.5.3 After the first minute the pressure shall be raised uniformly and at a rate not to exceed 0.7 kg/sq cm g/min.
 - 12.2.5.4 If any employee complains of discomfort, the pressure shall be held to determine if the symptoms are relieved. If, after 5 minutes the discomfort does not disappear, the lock attendant shall gradually reduce the pressure until the employee signals that the discomfort has ceased. If he does not indicate that the discomfort has disappeared, the lock attendant shall reduce the pressure to atmospheric and the employee shall be released from the lock.
 - 12.2.5.5 No employee shall be subjected to pressure exceeding 3.5 kg/sq cm g except in emergency.
- 12.2.6 Decompression
 - 12.2.6.1 Decompression to normal condition shall be in accordance with the Decompression Tables 12.0-1 and 12.0-2.
 - 12.2.6.2 In the event it is necessary for an employee to be in compressed air more than once in a 24-hour period, the appointed physician shall be responsible for the establishment of methods and procedures of decompression applicable to repetitive exposures.
 - 12.2.6.3 If decanting is necessary, the appointed physician shall establish procedures before any employee is permitted to be decompressed by decanting methods. The period

of time that the employees spend at atmospheric pressure between the decompression following the shift and recompression shall not exceed 5 minutes.

12.2.7 Man Locks

- 12.2.7.1 Except in emergency, no employees in compressed air shall be permitted to pass from the working chamber to atmospheric pressure until after decompression in accordance with the procedures in this paragraph.
- 12.2.7.2 The lock attendant in charge of a man lock shall be under the direct supervision of the appointed physician. The lock attendant shall be stationed at the lock controls on the free air side during the period of compression and decompression and shall remain at the lock control station whenever there are men in the working chamber or in the man lock.
- 12.2.7.3 Except where air pressure in the working chamber is below 0.84 kg/sq cm g, each man lock shall be equipped with automatic controls which, through taped programs, cams, or similar apparatus, shall automatically regulate decompressions. It shall also be equipped with manual controls to permit the lock attendant to override the automatic mechanism in the event of an emergency, as provided in subparagraph 12.2.7.8.
- 12.2.7.4 A manual control, which can be used in the event of an emergency, shall be placed inside the man lock.
- 12.2.7.5 A clock, thermometer, and continuous recording pressure gauge with a 4-hour graph shall be installed outside of each man lock and shall be changed prior to each shift's decompression. The chart shall be of sufficient size to register a legible record of variations in pressure within the man lock and shall be visible to the lock attendant. A copy of each graph shall be submitted to the appointed physician after each shift. In addition, a pressure gauge, clock, and thermometer shall also be installed in each man lock. Additional fittings shall be provided so that test gauges may be attached whenever necessary.
- 12.2.7.6 Except where air pressure is below 0.84 kg/sq cm g and there is no danger of rapid flooding, all caissons having a working area greater than 12.9 sq m and each bulkhead in tunnels of 4.2 m or more in diameter, or equivalent area, shall have at least two locks in perfect working condition, one of which shall be used exclusively as a man lock, the other, as a materials lock.
- 12.2.7.7 Where only a combination man-and-materials lock is required, this single lock shall be of sufficient capacity to hold the employees constituting two successive shifts.
- 12.2.7.8 Emergency locks shall be large enough to hold an entire heading shift and a limit maintained of 0.84 kg/sq cm g. There shall be a chamber available for oxygen decompression therapy to 1.97 kg/sq cm g.
- 12.2.7.9 The man lock shall be large enough so that those using it are not compelled to be in a cramped position, and shall not have less than 1.5 m clear head room at the center and a minimum of 0.85 cu m of air space per occupant.

- 12.2.7.10 Locks on caissons shall be so located that the bottom door shall be not less than 0.9 m above the water level surrounding the caisson on the outside. (The water level, where it is affected by tides, is construed to mean high tide).
- 12.2.7.11 In addition to the pressure gauge in the locks, an accurate pressure gauge shall be maintained on the outer and inner side of each bulkhead. These gauges shall be accessible at all times and shall be kept in accurate working order.
- 12.2.7.12 Man locks shall have an observation port at least 100 mm in diameter located in such a position that all occupants of the man lock may be observed from the working chamber and from the free air side of the lock.
- 12.2.7.13 Adequate ventilation shall be provided in the lock.
- 12.2.7.14 Man locks shall be maintained at a minimum temperature of 21°C.
- 12.2.7.15 When locks are not in use and employees are in the working chamber, lock doors shall be kept open to the working chamber, where practicable.
- 12.2.7.16 Provision shall be made to allow for rescue parties to enter the tunnel if the working force is disabled.
- 12.2.7.17 A special decompression chamber of sufficient size to accommodate the entire force of employees being decompressed at the end of a shift shall be provided whenever the regularly established working period requires a total time of decompression exceeding 75 min.
- 12.2.8 Special Decompression Chamber
- 12.2.8.1 The headroom in the special decompression chamber shall be not less than a minimum 2.1 m and the cubical content shall provide at least 1.4 cu.m of airspace for each employee. For each occupant, there shall be provided 0.4 sq m of free walking area and 0.3 sq m of seating space, exclusive of area required for lavatory and toilet facilities. The rated capacity shall be based on the above stated minimum space per employee and shall be posted at the chamber entrance. The posted capacity shall not be exceeded, except in case of emergency.
- 12.2.8.2 Each special decompression chamber shall be equipped with the following:
- A clock or clocks suitably placed so that the attendant and the chamber occupants can readily ascertain the time.
- Pressure gauges which will indicate to the attendants and to the chamber occupants the pressure in the chamber.
- Valves and pipes, in connection with the air supply and exhaust, arranged so that the chamber pressure can be controlled inside and outside.
- Effective means of oral intercommunication between the attendant, occupants of the chamber, and the air compressor plant.
- An observation port at the entrance to permit observation of the chamber occupants.

- 12.2.8.3 Seating facilities in special decompression chambers shall be so arranged as to permit a normal sitting posture without cramping. Seating space, not less than 45 cm x 60 cm wide, shall be provided per occupant.
- 12.2.8.4 Adequate toilet and washing facilities, in a screened or enclosed recess, shall be provided. Toilet bowls shall have a built-in protector on the rim so that an air space is created when the seat lid is closed.
- 12.2.8.5 Fresh and potable drinking water shall be available. This may be accomplished by either piping water into the special decompression chamber and providing drinkign fountains, or by providing individual canteens, or by some other sanitary means. Community drinking vessels are prohibited.
- 12.2.8.6 No refuse or discarded material of any kind shall be permitted to accumulate, and the chamber shall be kept clean.
- 12.2.8.7 Unless the special decompression chamber is serving as the man lock to atmospheric pressure, the special decompression chamber shall be situated, where practicable, adjacent to the man lock on the atmospheric pressure side of the bulkhead. A passageway shall be provided, connecting the special chamber with the man lock, to permit employees in the process of decompression to move from the man lock to the special chamber without a reduction in the ambient pressure from that designated for the next stage of decompression. The passageway shall be so arranged as to not interfere with the normal operation of the man lock, nor with the release of the occupants of the special chamber to atmospheric pressure upon the completion of the decompression procedure.
- 12.2.9 Compressor Plant and Air Supply
 - 12.2.9.1 At all times there shall be a thoroughly experienced, competent, and reliable person on duty at the air control valves as a gauge tender who shall regulate the pressure in the working areas. During tunneling operations, one gauge tender may regulate the pressure in not more than two headings; Provided, that the gauge and controls are all in one location. In caisson work, there shall be a gauge tender for each caisson.
 - 12.2.9.2 Low air compressor units shall have at least two independent and separate sources of power supply and each shall be capable of operating the entire low air plant and its accessory systems.
 - 12.2.9.3 Switching from one independent source of power supply to the other shall be done periodically to ensure the workability of the apparatus in an emergency.
 - 12.2.9.4 The capacity, arrangement, and number of compressors shall be sufficient to maintain the necessary pressure without overloading the equipment and to assure maintenance of such pressure in the working chamber during periods of breakdown, repair, or emergency.
 - 12.2.9.5 Duplicate low-pressure air feedlines and regulating valves shall be provided between the source of air supply and a point beyond the locks with one of the lines extending to within 30 m of the working face.
 - 12.2.9.6 All high - and low-pressure air supply lines shall be equipped with check valves.

- 12.2.9.7 Low-pressure air shall be regulated automatically. In addition, manually operated valves shall be provided for emergency conditions.
- 12.2.9.8 The air intakes for all air compressors shall be located at a place where fumes, exhaust gases, and other air contaminants will be at a minimum
- 12.2.9.9 Gauges indicating the pressure in the working chamber shall be installed in the compressor building, the lock attendant's station. and at the employer's field office.
- 12.2.10 Ventilation and Air Quality
 - 12.2.10.1 Exhaust valves and exhaust pipes shall be provided and operated so that the working chamber shall be ventilated, and there shall be no pockets of dead air. Outlets may be required at intermediate points along the main low-pressure air supply line to the heading to eliminate such pockets of dead air. Ventilating air shall be not less than 0.85 cu.m/min.
 - 12.2.10.2 The air in the workplace shall be analyzed by the employer not less than once each shift, and records of such tests shall be kept on file at the place where the work is in progress. The test results shall be within the threshold limit values specified in Sections 4.1 and 4.6 for hazardous gases, and within 10 percent of the lower explosive limit of flammable gases. If these limits are not met, immediate action to correct the situation shall be taken by the employer.
 - 12.2.10.3 The temperature of all working chambers which are subjected to air pressure shall, by means of after-coolers or other suitable devices, be maintained at a temperature not to exceed 30°C.
 - 12.10.4 Forced ventilation shall be provided during decompression. During the entire decompression period, forced ventilation through chemical or mechanical air purifying devices that will ensure a source of fresh air shall be provided.
 - 12.2.10.5 Whenever heat-producing machines (moles, shields) are used in compressed air tunnel operations, a positive means of removing the heat build-up at the heading shall be provided.
- 12.2.11 Electricity
 - i2.2.1 1.1 All lighting in compressed-air chambers shall be by electricity exclusively, and two independent electric-lighting systems with independent sources of supply shall be used. The emergency source shall be arranged to become automatically operative in the event of failure of the regularly used source.
 - 12.2.11.2 The minimum intensity of light on any walkway, ladder, stairway, or working level shall be not less than 100 lux, and in all workplaces the lighting shall be at least 300 lux.
 - 12.2.11.3 All electrical equipment, and wiring for light and power circuits, shall comply with requirements for use in damp, hazardous, high temperature, and compressed air environments.
 - 12.2.11.4 External parts of lighting fixtures and all other electrical equipment, when within 2.4 m of the floor, shall be constructed of noncombustible, nonabsorptive, insulating materials, except that metal may be used if it is effectively grounded.

- 12.2.11.5 Portable lamps shall be equipped with noncombustible, nonabsorptive, insulating sockets, approved handles, basket guards, and approved cords.
- 12.2.11.6 The use of worn or defective portable and pendant conductors is prohibited.
- 12.2.12 Sanitation
 - 12.2.12.1 Sanitary, heated, lighted, and ventilated dressing rooms and drying rooms shall be provided for all employees engaged in compressed air work. Such rooms shall contain suitable benches and lockers. Showers and toilets shall be provided in accordance with Section 2.6.
 - 12.2.12.2 When the toilet bowl is shut by a cover, there should be an air space so that the bowl or bucket does not implode when pressure is increased.
 - 12.2.12.3 All parts of caissons and other working compartments shall be kept in a sanitary conditions.
- 12.2.13 Fire Prevention and Protection
 - 12.2.13.1 Firefighting equipment shall be available at all times and shall be maintained in working condition.
 - 12.2.13.2 While welding or flame-cutting is being done in compressed air, a fire-watch with a fire hose or approved extinguisher shall stand by until such operation is completed.
 - 12.2.13.3 Shafts and caissons containing flammable material of any kind, either above or below ground, shall be provided with a waterline and a fire hose connected thereto, so arranged that all points of the shaft or caisson are within reach of the hose stream.
 - 12.2.13.4 Fire hose shall be at least 40 mm diameter; the water pressure shall at all times be adequate for efficient operation of the type of nozzle used; and the water supply shall be such as to ensure an uninterrupted flow. Fire hose, when not in use, shall be located or guarded to prevent injury thereto.
 - 12.2.13.5 The power house, compressor house, and all buildings housing ventilating equipment, shall be provided with at least one hose connection in the waterline, with a fire hose connected thereto. Air fire hose shall be maintained within reach of structures of wood over or near shafts.
 - 12.2.13.6 Tunnels shall be provided with a 50 mm minimum diameter waterline extending into the working chamber and to within 30 m of the working face. Such line shall have hose outlets with 30 m of fire hose attached and maintained as follows: One at the working face; one immediately inside of the bulkhead of the working chamber., and one immediately outside such bulkhead. In addition, those outlets shall be provided at 60 m intervals throughout the length of the tunnel, and 30 m of fire hose shall be attached to the outlet nearest to any location where flammable material is being kept or stored or where any flame is being used.
 - 12.2.13.7 In addition to fire hose protection required on every floor of every building not under compressed air, but used in connection with the compressed air work, there shall be provided at least one approved fire extinguisher of the proper type for the hazard involved. At least two approved fire extinguishers shall be provided in the working chamber as follows: One at the working face and one immediately inside

the bulkhead (pressure side). Extinguishers in the working chamber shall use water as the primary extinguishing agent and shall not use any extinguishing agent which could be harmful to the employees in the working chamber. The fire extinguisher shall be protected from damage.

- 12.2.13.8 Highly combustible materials shall not be used or stored in the working chamber. Wood, paper, and similar combustible material shall not be used in the working chamber in quantities which could cause a fire hazard. The compressor building shall be constructed of noncombustible material.
- 12.2.13.9 Man locks shall be equipped with a manual type fire extinguisher system that can be activated inside the man lock and also by the outside lock attendant. In addition, a fire hose and portable fire extinguisher shall be provided inside and outside the man lock. The portable fire extinguisher shall be the dry chemical type.
- 12.2.13.10 Equipment, fixtures, and furniture in man locks and special decompression chambers shall be constructed of noncombustible materials. Bedding, etc., shall be chemically treated so as to be fire resistant.
- 12.2.13.11 Head frames shall be constructed of structural steel or open frame-work fireproofed timber. Head houses and other temporary surface buildings or structures within 30 m of the shaft, caisson, or tunnel opening shall be built of fire-resistant materials.
- 12.2.13.12 No oil, gasoline, or other combustible material shall be stored within 30 m of any shaft, caisson, or tunnel opening, except that oils may be stored in suitable tanks in isolated fireproof buildings, provided such buildings are not less than 15 m from any shaft, caisson, or tunnel opening, or any building directly connected thereto.
- 12.2.13.13 Positive means shall be taken to prevent leaking flammable liquids from flowing into the areas specifically mentioned in the preceding subparagraph.
- 12.2.13.14 All explosives used in connection with compressed air work shall be selected, stored, transported, and used as specified in Section 4.4.
- 12.2.14 Bulkheads and Safety Screens
 - 12.2.14.1 Intermediate bulkheads with locks, or intermediate safety screens or both, are required where there is the danger of rapid flooding.
 - 12.2.14.2 In tunnels 4.8 m or more in diameter, hanging walkways shall be provided from the face to the man lock as high in the tunnel as practicable, with at least 1.8 m of head room. Walkways shall be constructed of noncombustible material. Standard railings shall be securely installed throughout the length of all walkways on open sides in accordance with paragraph 2.5.5. Where walkways are ramped under safety screens, the walkway surface shall be skidproofed by cleats or by equivalent means.
 - 12.2.14.3 Bulkheads used to contain compressed air shall be tested, where practicable, to prove their ability to resist the highest air pressure which may be expected to be used.

12.3 Decompression Tables

12.3.1 Explanation. The decompression tables are computed for working chamber pressures from 0 to 0.98 kg/sq cm g and from 0.98 to 3.52 kg/sq cm g and for exposure times for each pressure extending from one-half to over 8 hours inclusive. Decompressions shall be conducted by two or more stages with a maximum of four stages, the latter for a working chamber pressure of 2.81 kg/sq cm g or over.

Stage 1 Consists of a reduction in ambient Pressure ranging from 0.70 to a maximum of 1.12 kg/sq cm g but in no instance will the pressure be reduced below 0.28 kg/sq cm g at the end of stage 1. This reduction in pressure in stage 1 will always take place at a rate not greater than 0.35 kg/sq cm g/min.

Further reduction in pressure will take place during stage 2 and subsequent stages as required at a slower rate. but in no event at a rate greater than 0.07 kg/sq cm g/min.

Decompression Table 12.0-1 indicates the total decompression time in minutes for various combinations of working chamber pressure and exposure time.

Decompression Table 12.0-2 indicates for the same various combinations of working chamber pressure and exposure time the following:

- The number of stages required;
- The reduction in pressure and the terminal pressure for each required stage;
- The time in minutes through which the reduction in pressure is accomplished for each required stage;
- The pressure reduction rate in kg/sq cm/min. for each required stage;

IMPORTANT: The pressure reduction in each stage is accomplished at a uniform rate. Do not interpolate between values shown in the Tables. Use the next higher value of working chamber pressure or exposure time should the actual working chamber pressure or the actual exposure time, respectively, fall between those for which calculated values are shown in the body of the Tables.

Examples:

Example No. 1:

4 hours working period at 1.41 kg/sq cm g.

Decompression Table 12.0-1:

1.41 kg/sq cm for 4 hours, total decompression time = 43 min.

Decompression Table 12.0-2:

Stage 1: Reduce pressure from 1.41 to .28 kg/sq cm g at the uniform rate of .35 kg/sq cm/min.

$$\text{Elapsed time stage 1: } \frac{1.41 - .28}{.35} = 3 \text{ min.}$$

Stage 2 (final stage): Reduce pressure at a uniform rate from .28 to 0 kg/sq cm g over a period of 40 min.

Rate --- .007 kg/sq cm/min.

Stage 2 (final) elapsed time.

= 40 min.

Total Time

= 43 min.

Example No. 2:

5-hour working period at 1.69 kg/sq cm gauge.

Decompression Table 12.0-1:

1.69 kg/sq cm g for 5 hrs, total decompression time

117min.

Decompression Table 12.0-2:

Stage 1: Reduce pressure from 1.69 to .56 kg/sq cm g at the uniform rate of .35 kg/sq cm/min.

Elapsed time stage 1: $\frac{1.13}{.35}$

3 min.

Stage 2: Reduce pressure at a uniform rate

from .56 to .28 kg/sq cm g over a period of 4 min.

Rate, .07 kg/sq cm/min elapsed time, stage 2

= 4 min.

Transfer men to special decompression chamber

maintaining the .28 kg/sq cm pressure during the transfer operation.

Stage 3: (Final Stage): In the special decompression

chamber, reduce the pressure at a uniform

rate from .28 to 0 kg/sq cm g over a period of

110 min. Rate, .003/kg/sq cm/min.

Stage 3 (final) elapsed time

= 110min.

Total Time

= 117 min.

Decompression Table No. 12.0-1
Total decompression time (In minutes)

Work pressure Kg/sq. cm. g.	Working period (Hours)										
	.5	1	1.5	2	3	4	5	6	7	8	Over 8
0 - .84	3	3	3	3	3	3	3	3	3	3	3
.98	6	6	6	6	6	6	6	6	16	16	33
1.12	7	7	7	7	7	7	17	33	48	48	62
1.27	7	7	7	8	11	17	48	63	63	73	87
1.41	7	7	8	15	15	43	63	73	83	103	113
1.55	9	9	16	24	38	68	93	103	113	128	133
1.69	11	12	23	27	52	92	117	122	127	137	151
1.83	13	14	29	34	69	104	126	141	142	142	163
1.97	15	23	31	41	98	127	143	153	153	165	183
2.11	17	28	38	62	105	143	165	168	178	188	204
2.25	19	35	43	85	126	163	178	193	203	213	226
2.39	21	39	58	98	151	178	195	218	223	233	248
2.53	24	44	63	113	170	198	223	233	243	253	273
2.67	28	49	73	128	178	203	223	238	253	263	278
2.81	31	49	84	143	183	213	233	248	258	268	288
2.95	37	56	102	144	189	215	245	260	263	268	293
3.09	43	64	118	154	199	234	254	264	269	269	293
3.23	44	74	139	171	214	244	269	274	289	299	318
3.37	51	89	144	189	229	269	299	309	319	319	—
3.50	58	94	164	209	249	279	309	329	—	—	—

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
.98	0.5	1	.98	.28	2	.35	6
		2	.28	0	4	.07	
	1	1	.98	.28	2	.35	6
		2	.28	0	4	.07	
	1.5	1	.98	.28	2	.35	6
		2	.28	0	4	.07	
	2	1	.98	.28	2	.35	6
		2	.28	0	4	.07	
	3	1	.98	.28	2	.35	6
		2	.28	0	4	.07	
	4	1	.98	.28	2	.35	6
		2	.28	0	4	.07	
	5	1	.98	.28	2	.35	6
		2	.28	0	4	.07	
	6	1	.98	.28	2	.35	6
		2	.28	0	4	.07	
	7	1	.98	.28	2	.35	16
		2	.28	0	14	.07	
	8	1	.98	.28	2	.35	16
		2	.28	0	14	.02	
	Over 8	1	.98	.28	2	.35	33
		2	.28	0	31	.01	
1.12..	0.5	1	1.12	0.28	3	.28	7
		2	.28	0	4	.07	
	1	1	1.12	0.28	3	.28	7
		2	.28	0	4	.07	
	1.5	1	1.12	0.28	3	.28	7
		2	.28	0	4	.07	
	2	1	1.12	0.28	3	.28	7
		2	.28	0	4	.07	
	3	1	1.12	0.28	3	.28	7
		2	.28	0	4	.07	
	4	1	1.12	0.28	3	.28	7
		2	.28	0	4	.07	
	5	1	1.12	0.28	3	.28	17
		2	.28	0	14	.07	
	6	1	1.12	0.28	3	.28	33
		2	.28	0	30	.01	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.	
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.			
			From	To				
1.12	7	1	1.12	.28	3	.28	48	
		2	.28	0	45	.006		
	8	1	1.12	.28	3	.28	48	
		2	.28	0	45	.006		
	Over 8	1	1.12	.28	3	.07	62	
2		.28	0	59	.005			
1.27	.5	1	1.27	.28	3	.33	7	
		2	.28	0	4	.07		
	1	1	1.27	.28	3	.33	7	
		2	.28	0	4	.07		
	1.5	1	1.27	.28	3	.33	7	
		2	.28	0	4	.07		
	2	1	1.27	.28	3	.33	8	
		2	.28	0	5	.056		
	3	1	1.27	.28	3	.33	11	
		2	.28	0	8	.035		
	4	1	1.27	.28	3	.33	17	
		2	.28	0	14	.02		
	5	1	1.27	.28	3	.33	48	
		2	.28	0	45	.006		
	6	1	1.27	.28	3	.33	63	
		2	.28	0	60	.005		
	7	1	1.27	.28	3	.33	63	
		2	.28	0	60	.005		
	8		1.27	.28	3	.33	73	
		2	.28	0	70	.004		
	Over 8	1	1.27	.28	3	.33	87	
		2	.28	0	84	.003		
	1.41	.5	1	1.41	.28	3	.35	7
			2	.28	0	4	.07	
		1	1	1.41	.28	3	.35	7
			2	.28	0	4	.07	
		1.5	1	1.41	.28	3	.35	8
2			.28	0	5	.056		
2		1	1.41	.28	3	.35	15	
		2	.28	0	12	.023		

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
1.41..	3	1	1.41	.28	3	.35	15
		2	.28	0	12	.023	
	4	1	1.41	.28	3	.35	43
		2	.28	0	40	.007	
	5	1	1.41	.28	3	.35	63
		2	.28	0	60	.005	
	6	1	1.41	.28	3	.35	73
		2	.28	0	70	.004	
	7	1	1.41	.28	3	.35	83
		2	.28	0	80	.004	
	8	1	1.41	.28	3	.35	103
		2	.28	0	100	.003	
	Over 8	1	1.41	.28	3	.35	113
		2	.28	0	110	.003	
15.5	.5	1	1.55	.42	3	.35	9
		2	.42	0	6	.07	
	1	1	1.55	.42	3	.35	9
		2	.42	0	6	.07	
	1.5	1	1.55	.42	3	.35	16
		2	.42	0	13	.032	
	2	1	1.55	.42	3	.35	24
		2	.42	0	21	0.02	
	3	1	1.55	.42	3	.35	38
		2	.42	0	35	.012	
	4	1	1.55	.42	3	.35	68
		2	.42	0	65	.006	
	5	1	1.55	.42	3	.35	93
		2	.42	0	90	.005	
	6	1	1.55	.42	3	.35	103
		2	.42	0	100	.004	
	7	1	1.55	.42	3	.35	113
		2	.42	0	110	.004	
	8	1	1.55	.42	3	.35	128
		2	.42	0	125	.003	
	Over 8	1	1.55	.42	3	.35	133
		2	.42	0	130	.003	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
1.69	.5	1	1.69	.56	3	.35	11
		2	.56	.28	4	.07	
		3	.28	0	4	.07	
	1	1	1.69	.56	3	.35	12
		2	.56	.28	4	.07	
		3	.28	0	5	.056	
	1.5	1	1.69	.56	3	.35	23
		2	.56	.28	4	.07	
		3	.28	0	16	.018	
	2	1	1.69	.56	3	.35	27
		2	.56	.28	4	.07	
		3	.28	0	20	.014	
	3	1	1.69	.56	3	.35	52
		2	.56	.28	4	.07	
		3	.28	0	45	.005	
	4	1	1.69	.56	3	.35	9.2
		2	.56	.28	4	.07	
		3	.28	0	85	.003	
	5	1	1.69	.56	3	.35	117
		2	.56	.28	4	.07	
		3	.28	0	110	.003	
	6	1	1.69	.56	3	.35	122
		2	.56	.28	4	.07	
		3	.28	0	115	.002	
	7	1	1.69	.56	3	.35	127
		2	.56	.28	4	.07	
		3	.28	0	120	.002	
	8	1	1.69	.56	3	.35	137
		2	.56	.28	4	.07	
		3	.28	0	130	.002	
	9	1	1.69	.56	3	.35	151
		2	.56	.28	8	.07	
		3	.28	0	140	.002	
	Over 8						
1.83	0.5	1	1.83	.70	3	.35	13
		2	.70	.28	6	.07	
		3	.28	0	4	.07	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data			Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.	
		Stage No.	Pressure reduction Kg/sq cm				Time in Stage min.
			From	To			
1.83	1	1	1.83	.70	3	.35	14
		2	.70	.28	6	.07	
		3	.28	0	5	.056	
	1.5	1	1.83	.70	3	.35	29
		2	.70	.28	6	.07	
		3	.28	0	20	.014	
	2	1	1.83	.70	3	.35	34
		2	.70	.28	6	.07	
		3	.28	0	25	.011	
	3	1	1.83	.70	3	.35	69
		2	.70	.28	6	.07	
		3	.28	0	60	.005	
	4	1	1.83	.70	3	.35	104
		2	.70	.28	6	.07	
		3	.28	0	95	.003	
	5	1	1.83	.70	3	.35	126
		2	.70	.28	8	.053	
		3	.28	0	115	.002	
	6	1	1.83	.70	3	.35	141
		2	.70	.28	8	.053	
		3	.28	0	130	.002	
	7	1	1.83	.70	3	.35	142
		2	.70	.28	9	.047	
		3	.28	0	130	.002	
	8	1	1.83	.70	3	.35	142
		2	.70	.28	9	.047	
		3	.28	0	130	.002	
Over 8	1	1.83	.70	3	.35	163	
	2	.70	.28	30	.014		
	3	.28	0	130	.002		

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
1.97	.5	1	1.97	.84	3	.35	15
		2	.84	.28	8	.07	
		3	.28	0	4	.07	
	1	1	1.97	.84	3	.35	23
		2	.84	.28	8	.07	
		3	.28	0	12	.023	
	1.5	1	1.97	.84	3	.35	31
		2	.84	.28	8	.07	
		3	.28	0	20	.014	
	2	1	1.97	.84	3	.35	41
		2	.84	.28	8	.07	
		3	.28	0	30	.009	
	3	1	1.97	.84	3	.35	98
		2	.84	.28	10	.056	
		3	.28	0	85	.003	
	4	1	1.97	.84	3	.35	127
		2	.84	.28	14	0.04	
		3	.28	0	110	.003	
	5	1	1.97	.84	3	.35	143
		2	.84	.28	20	.028	
		3	.28	0	120	.002	
	6	1	1.97	.84	3	.35	153
		2	.84	.28	20	.028	
		3	.28	0	130	.002	
	7	1	1.97	.84	3	.35	153
		2	.84	.28	20	0.028	
		3	.28	0	130	.002	
	8	1	1.97	.84	3	.35	165
		2	.84	.28	32	.018	
		3	.28	0	130	.002	
	Over 8	1	1.97	.84	3	.35	183
		2	.84	.28	50	.006	
		3	.28	0	130	.002	
2.11	5	1	2.11	.98	3	.35	17
		2	.98	.28	10	.07	
		3	.28	0	4	.07	
	1	1	2.11	.98	3	.35	28
		2	.98	.28	10	.07	
		3	.28	0	15	.019	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
2.11	1.5	1	2.11	.98	3	.35	38
		2	.98	.28	10	.07	
		3	.28	0	25	.011	
	2	1	2.11	.98	3	.35	62
		2	.98	.28	14	.05	
		3	.28	0	45	.006	
	3	1	2.11	.98	3	.35	105
		2	.98	.28	17	0.041	
		3	.28	0	85	.003	
	4	1	2.11	.98	3	.35	143
		2	.98	.28	30	.023	
		3	.28	0	110	.003	
	5	1	2.11	.98	3	.35	165
		2	.98	.28	32	.022	
		3	.28	0	130	.002	
	6	1	2.11	.98	3	.35	168
		2	.98	.28	35	.02	
		3	.28	0	130	.002	
	7	1	2.11	.98	3	.35	178
		2	.98	.28	45	.016	
		3	.28	0	130	.002	
	8	1	2.11	.98	3	.35	188
		2	.98	.28	55	.013	
		3	.28	0	130	.002	
	Over 8	1	2.11	.98	3	.35	204
		2	.98	.28	71	.01	
		3	.28	0	130	.002	
2.25	.5	1	2.25	1.12	3	.35	19
		2	1.12	.28	12	.07	
		3	.28	0	4	.07	
	1	1	2.25	1.12	3	.35	35
		2	1.12	.28	12	.07	
		3	.28	0	20	.014	
	1.5	1	2.25	1.12	3	.35	43
		2	1.12	.28	15	.056	
		3	.28	0	25	.011	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data			Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.	
		Stage No.	Pressure reduction Kg/sq cm				Time in Stage min.
			From	To			
2.25	2	1	2.25	1.12	3	.35	85
		2	1.12	.28	22	.38	
		3	.28	0	60	.005	
	3	1	2.25	1.12	3	.35	126
		2	1.12	.28	28	.03	
		3	.28	0	95	.003	
	4	1	2.25	1.12	3	.35	163
		2	1.12	.28	40	.021	
		3	.28	0	120	.002	
	5	1	2.25	1.12	3	.35	178
		2	1.12	.28	45	.019	
		3	.28	0	130	.002	
	6	1	2.25	1.12	3	.35	193
		2	1.12	.28	60	.005	
		3	.28	0	130	.002	
	7	1	2.25	1.12	3	.35	203
		2	1.12	.28	70	.012	
		3	.28	0	130	.002	
	8	1	2.25	1.12	3	.35	213
		2	1.12	.28	80	.011	
		3	.28	0	130	.002	
	Over 8	1	2.25	1.12	3	.35	226
		2	1.12	.28	93	0.009	
		3	.28	0	130	.002	
2.39	.5	1	2.39	1.26	3	.35	21
		2	1.26	.28	14	.07	
		3	.28	0	4	.07	
	1	1	2.39	1.26	3	.35	39
		2	1.26	.28	14	.07	
		3	.28	0	22	.013	
	1.5	1	2.39	1.26	3	0.35	58
		2	1.26	.28	25	.039	
		3	.28	0	30	.009	
	2	1	2.39	1.26	3	.35	98
		2	1.26	.28	35	.008	
		3	.28	0	60	.005	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.	
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.			
			From	To				
2.39..	3	1	2.39	1.26	3	.35	151	
		2	1.26	.28	43	.023		
		3	.28	0	105	.003		
	4	1	2.39	1.26	3	.35	178	
		2	1.26	.28	55	.018		
		3	.28	0	120	.002		
	5	1	2.39	1.26	3	.35	195	
		2	1.26	.28	62	.016		
		3	.28	0	130	.002		
	6	1	2.39	1.26	3	.35	218	
		2	1.26	.28	85	.012		
		3	.28	0	130	.002		
	7	1	2.39	1.26	3	.35	223	
		2	1.26	.28	90	.011		
		3	.28	0	130	.002		
	8	1	2.39	1.26	3	.35	233	
		2	1.26	.28	100	.01		
		3	.28	0	130	.002		
	Over 8	1	2.39	1.26	3	.35	248	
		2	1.26	.28	115	.009		
		3	.28	0	130	.002		
	2.53	.5	1	2.53	1.41	3	.35	24
			2	1.41	.28	16	.07	
			3	.28	0	5	.056	
		1	1	2.53	1.41	3	.35	44
			2	1.41	.28	16	.07	
			3	.28	0	25	0.11	
		1.5	1	2.53	1.41	3	.35	63
			2	1.41	.28	30	0.38	
			3	.28	0	30	.009	
		2	1	2.53	1.41	3	.35	113
			2	1.41	.28	40	.028	
			3	.28	0	70	.004	
		3	1	2.53	1.41	3	.35	170
			2	1.41	.28	52	.022	
			3	.28	0	115	.002	
4		1	2.53	1.41	3	.35	198	
		2	1.41	.28	65	.017		
		3	.28	0	130	.002		

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
2.53.. <							

Decompression Table No. 12.0-2

(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
2.67 <							

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
2.81	5	1	2.81	1.69	3	.35	233
		2	1.69	.56	47	.024	
		3	.56	.28	53	.005	
		4	.28	0	130	.002	
	6	1	2.81	1.69	3	.35	248
		2	1.69	.56	55	.021	
		3	.56	.28	60	.005	
		4	.28	0	130	.002	
	7	1	2.81	1.69	3	.35	258
		2	1.69	.56	65	.017	
		3	.56	.28	60	.005	
		4	.28	0	130	.002	
	8	1	2.81	1.69	3	.35	168
		2	1.69	.56	75	.015	
		3	.56	.28	60	.005	
		4	.28	0	130	.002	
	Over 8	1	2.81	1.69	3	.35	288
		2	1.69	.56	95	.012	
		3	.56	.28	60	.005	
		4	.28	0	130	.002	
2.95	.5	1	2.95	1.83	3	.35	37
		2	1.83	.70	16	.07	
		3	.70	.28	6	.07	
		4	.28	0	12	.023	
	1	1	2.95	1.83	3	.35	56
		2	1.83	.70	16	.07	
		3	.70	.28	12	.023	
		4	.28	0	25	.011	
	1.5	1	2.95	1.83	3	.35	102
		2	1.83	.70	16	.07	
		3	.70	.28	23	.018	
		4	.28	0	60	.005	
	2	1	2.95	1.83	3	.35	144
		2	1.83	.70	16	.07	
		3	.70	.28	30	.014	
		4	.28	0	95	.003	
	3	1	2.95	1.83	3	.35	189
		2	1.83	.70	16	.07	
		3	.70	.28	50	.008	
		4	.28	0	120	.002	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
2.95	4	1	2.95	1.83	3	.35	215
		2	1.83	.70	17	.066	
		3	.70	.28	65	.006	
		4	.28	0	130	.002	
	5	1	2.95	1.83	3	.35	245
		2	1.83	.70	27	.042	
		3	.70	.28	85	.005	
		4	.28	0	130	.002	
	6	1	2.95	1.83	3	.35	260
		2	1.83	.70	27	.042	
		3	.70	.28	100	.004	
		4	.28	0	130	.002	
	7	1	2.95	1.83	3	.35	263
		2	1.83	.70	30	.038	
		3	.70	.28	100	.004	
		4	.28	0	130	.002	
	8	1	2.95	1.83	3	.35	268
		2	1.83	.70	35	.032	
		3	.70	.28	100	.004	
		4	.28	0	130	.002	
	Over 8	1	2.95	1.83	3	.35	293
		2	1.83	.70	60	.019	
		3	.70	.28	100	.004	
		4	.28	0	130	.002	
3.09	.5	1	3.09	1.97	3	.35	43
		2	1.97	.84	16	.07	
		3	.84	.28	8	.07	
		4	.28	0	16	.018	
	1	1	3.09	1.97	3	.35	64
		2	1.97	.84	16	.07	
		3	.84	.28	20	.028	
		4	.28	0	25	.011	
	1.5	1	3.09	1.97	3	.35	118
		2	1.97	.84	16	.07	
		3	.84	.28	27	.021	
		4	.28	0	72	.004	
	2	1	3.09	1.97	3	.35	154
		2	1.97	.84	16	.07	
		3	.84	.28	40	.014	
		4	.28	0	95	.002	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
3.09..	3	1	3.09	1.97	3	.35	199
		2	1.97	.84	16	.07	
		3	.84	.28	60	.009	
		4	.28	0	120	.002	
	4	1	3.09	1.97	3	.35	234
		2	1.97	.84	16	.07	
		3	.84	.28	85	.007	
		4	.28	0	130	.002	
	5	1	3.09	1.97	3	.35	254
		2	1.97	.84	16	.07	
		3	.84	.28	105	.005	
		4	.28	0	130	.002	
	6	1	3.09	1.97	3	.35	264
		2	1.97	.84	16	.07	
		3	.84	.28	115	.005	
		4	.28	0	130	.002	
	7	1	3.09	1.97	3	.35	269
		2	1.97	.84	16	.07	
		3	.84	.28	120	.005	
		4	.28	0	130	.002	
	8	1	3.09	1.97	3	.35	269
		2	1.97	.84	16	.07	
		3	.84	.28	120	.005	
		4	.28	0	130	.002	
	Over 8	1	3.09	1.97	3	.35	293
		2	1.97	.84	40	.028	
		3	.84	.28	120	.005	
		4	.28	0	130	.002	
3.23	.5	1	3.23	2.11	3	.35	44
		2	2.11	.98	16	.07	
		3	.98	.28	10	.07	
		4	.28	0	15	.019	
	1	1	3.23	2.11	3	.35	74
		2	2.11	.98	16	.07	
		3	.98	.28	25	.028	
		4	.28	0	30	.009	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
3.23	1.5	1	3.23	2.11	3	.35	139
		2	2.11	.98	16	.07	
		3	.98	.28	35	.02	
		4	.28	0	85	.003	
	2	1	3.23	2.11	3	.35	171
		2	2.11	.98	16	.07	
		3	.98	.28	47	.015	
		4	.28	0	105	.003	
	3	1	3.23	2.11	3	.35	214
		2	2.11	.98	16	.07	
		3	.98	.28	65	.011	
		4	.28	0	130	.002	
	4	1	3.23	2.11	3	.35	244
		2	2.11	.98	16	.07	
		3	.98	.28	95	.007	
		4	.28	0	130	.002	
	5	1	3.23	2.11	3	.35	269
		2	2.11	.98	16	.07	
		3	.98	.28	120	.006	
		4	.28	0	130	.002	
	6	1	3.23	2.11	3	.35	274
		2	2.11	.98	16	.07	
		3	.98	.28	125	.006	
		4	.28	0	130	.002	
	7	1	3.23	2.11	3	.35	289
		2	2.11	.98	16	.07	
		3	.98	.28	140	.005	
		4	.28	0	130	.002	
	8	1	3.23	2.11	3	.35	299
		2	2.11	.98	16	.07	
		3	.98	.28	150	.005	
		4	.28	0	130	.002	
	Over 8	1	3.23	2.11	3	.35	318
		2	2.11	.98	25	.045	
		3	.98	.28	160	.004	
		4	.28	0	130	.002	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
3.37	.5	1	3.37	2.25	3	.35	51
		2	2.25	1.12	16	.07	
		3	1.12	.28	12	.007	
		4	.28	0	20	.014	
	1	1	3.37	2.25	3	.35	89
		2	2.25	1.12	16	.07	
		3	1.12	.28	35	.024	
		4	.28	0	35	.008	
	1.5	1	3.37	2.25	3	.35	144
		2	2.25	1.12	16	.07	
		3	1.12	.28	45	.019	
		4	.28	0	80	.004	
	2	1	3.37	2.25	3	.35	189
		2	2.25	1.12	16	.07	
		3	1.12	.28	60	.014	
		4	.28	0	110	.003	
	3	1	3.37	2.25	3	.35	229
		2	2.25	1.12	16	.07	
		3	1.12	.28	90	.009	
		4	.28	0	130	.002	
	4	1	3.37	2.25	3	.35	269
		2	2.25	1.12	16	.07	
		3	1.12	.28	120	.007	
		4	.28	0	130	.002	
	5	1	3.37	2.25	3	.35	299
		2	2.25	1.12	16	.07	
		3	1.12	.28	140	.006	
		4	.28	0	130	.002	
	6	1	3.37	2.25	3	.35	309
		2	2.25	1.12	16	.07	
		3	1.12	.28	160	.005	
		4	.28	0	130	.002	
	7	1	3.37	2.25	3	.35	319
		2	2.25	1.12	16	.07	
		3	1.12	.28	170	.005	
		4	.28	0	130	.319	

Decompression Table No. 12.0-2
(Do not interpolate, use next higher value for conditions not computed)

Working Chamber Pressure Kg/sq cm g	Working Period hrs	Decompression data				Pressure Reduction Rate kg/sq cm/min.	Total Decompress min.
		Stage No.	Pressure reduction Kg/sq cm		Time in Stage min.		
			From	To			
3.37	8	1	3.37	2.25	3	.35	319
		2	2.25	1.12	16	.07	
		3	1.12	.28	170	.005	
		4	.28	0	130	.002	
3.50	.5	1	3.50	2.39	3	.35	58
		2	2.39	1.27	16	.07	
		3	1.27	.28	14	.07	
		4	.28	0	25	.011	
	1	1	3.50	2.39	3	.35	94
		2	2.39	1.27	16	.07	
		3	1.27	.28	40	.025	
		4	.28	0	35	.008	
	1.5	1	3.50	2.39	3	.35	164
		2	2.39	1.27	16	.07	
		3	1.27	.28	55	.018	
		4	.28	0	90	.003	
	2	1	3.50	2.39	3	.35	209
		2	2.39	1.27	16	.07	
		3	1.27	.28	70	.014	
		4	.28	0	120	.002	
	3	1	3.50	2.39	3	.35	249
		2	2.39	1.27	16	.07	
		3	1.27	.28	100	.01	
		4	.28	0	130	.002	
	4	1	3.50	2.39	3	.35	279
		2	2.39	1.27	16	.07	
		3	1.27	.28	130	.008	
		4	.28	0	130	.002	
	5	1	3.50	2.39	3	.35	309
		2	2.39	1.27	16	.07	
		3	1.27	.28	160	.006	
		4	.28	0	130	.002	
	6	1	3.50	2.39	3	.35	329
		2	2.39	1.27	16	.07	
		3	1.27	.28	180	.006	
		4	.28	0	130	.002	

12.4 Tunnels and Shafts**12.4.1 General**

- 12.4.1.1 Safe means of access shall be provided and maintained to all working places.
- 12.4.1.2 When ladders and stairways are provided in shafts and steep inclines, they shall meet the requirements of Sections 2.3 and 2.4.
- 12.4.1.3 Access to unattended underground openings shall be restricted by gates or doors. Unused chutes, manways, or other openings shall be tightly covered, bulkheaded, or fenced off and posted. Conduits, trenches and manholes shall meet the requirements of Sections 2.5 and 9.0.
- 12.4.1.4 Subsidence areas that present hazards shall be fenced and posted.
- 12.4.1.5 Each operation shall have a check-in and check-out system that will provide positive identification of every employee underground. An accurate record and location of the employees shall be kept on the surface.

12.4.2 Emergency Provisions

- 12.4.2.1 Evacuation plans and procedures shall be developed and made known to each employee.
- 12.4.2.2 Emergency hoisting facilities shall be readily available at shafts more than 15 m in depth, unless hoisting facilities are provided that are independent of electrical power failures. A boatswain's chair shall meet the requirements of Section 6.9.
- 12.4.2.3 Approved self-rescuers shall be available near the advancing face to equip each face employee. Such equipment shall be on the haulage equipment and in other areas where employees might be trapped by smoke or gas, and shall be maintained in good condition.
- 12.4.2.4 Telephone or other signal communication shall be provided between the work face and the tunnel portal, and such systems shall be independent of the tunnel power supply.

12.4.3 Air Quality and Ventilation**12.4.3.1 Air Quality**

- 12.4.3.1.1 Instruments shall be provided to test the atmosphere quantitatively for carbon monoxide, nitrogen dioxide, flammable or toxic gases, dusts, mists, and fumes that occur in the tunnel or shaft. Tests shall be conducted as frequently as necessary to assure that the required quality of air is maintained. A record of all tests shall be maintained and be kept available.
- 12.4.3.1.2 Field-type oxygen analysers, or other suitable devices, shall be used to test for oxygen deficiency.
- 12.4.3.1.3 Respirators shall not be substituted for environmental control measures. However, where environmental controls have not yet been developed, or when necessary by the nature of the work involved (for example, welding, sand blasting, lead burning), an employee may work for short periods of time in concentrations

of airborne contaminants which exceed the permissible limits referred to in subparagraphs 12.4.3.1.4 and 12.4.3.1.5, if such employee wears a respiratory protective device approved as protection against the particular hazards involved.

- 12.4.3.1.4 The exposure to airborne contaminants of an employee working in a tunnel or shaft shall not exceed the threshold limit values of Section 4.6.
- 12.4.3.1.5 Atmospheres in all active areas shall contain at least 19.5 percent oxygen.
- 12.4.3.2 Ventilation
 - 12.4.3.2.1 Tunnels shall be provided with mechanically induced primary ventilation in all work areas. The direction of airflow shall be reversible.
 - 12.4.3.2.2 Ventilation doors, not operated mechanically, shall be designed and installed so that they are self-closing and will remain closed regardless of the direction of the air movement.
 - 12.4.3.2.3 When there has been failure of ventilation, and ventilation has been restored in a reasonable time, all places where flammable gas may have accumulated shall be examined by a competent person and determined to be free of flammable gas before power is restored and work resumed.
 - 12.4.3.2.4 When the main fan or fans have been shut down with all employees out of the adit, tunnel, or shaft. no employee, other than those qualified to examine the adit, tunnel, or shaft, or other authorized employee, shall go underground until the fans have been started, the work areas examined for gas and other hazards, and declared safe.
 - 12.4.3.2.5 The supply of fresh air shall not be less than 5.7 cu m/min. for each employee underground. The linear velocity of the air flow in the tunnel bore shall not be less than 9 m/min. in those tunnels where blasting or rock drilling is conducted or where there are other conditions that are likely to produce dusts, fumes, vapors, or gases in harmful quantities.
 - 12.4.3.2.6 If 1.5 percent or higher concentration of flammable gas is detected in air returning from a underground working place or places, the employees shall be withdrawn and the power cut off to the portion of the area endangered by such flammable gas until the concentration of such gas is reduced to 1 percent or less.
 - 12.4.3.2.7 Internal combustion engines shall not be used underground.
- 12.4.4 Illumination. Sufficient lighting shall be provided, in accordance with the requirements of Table 7.4-2 of Section 7.4 to permit safe operations at the face as well as in the general tunnel or shaft area and at the employee' workplace.
- 12.4.5 Fire Prevention and Control
 - 12.4.5.1 The requirements for fire prevention and protection specified in Section 2.7 shall be complied with in all tunnel and shaft operations.
 - 12.4.5.2 Signs warning against smoking and open flames shall be posted so that they can be readily seen in areas or places where fire or explosion hazards exist.

- 12.4.5.3 The carrying of matches, lighters, or other flame-producing materials shall be prohibited in all underground operations where fire or explosion hazards exist.
- 12.4.5.4 Gasoline or liquefied petroleum gas shall not be taken, stored, or used underground.
- 12.4.5.5 Oil or grease stored underground shall be kept in tightly sealed containers in fire-resistant areas, at safe distances from explosives magazines; electrical installations, and shaft stations.
- 12.4.5.6 Air that has passed through underground oil or grease-storage areas shall not be used to ventilate working areas.
- 12.4.5.7 Approved fire-resistant hydraulic fluids shall be used in hydraulically actuated underground machinery and equipment.
- 12.4.5.8 Fires shall not be built underground.
- 12.4.5.9 Noncombustible barriers shall be installed below welding or burning operations in or over a shaft or in or under a raise.
- 12.4.5.10 Fire extinguishers or equivalent protection shall be provided at the head and tail pulleys of underground belt conveyors and at 90 m intervals along the belt line.
- 12.4.5.11 At tunnel operations employing 25 or more employees at one time underground, at least two rescue crews (10 employees divided between shifts) shall be trained annually in rescue procedures, in the use, care, and limitations of oxygen breathing apparatus, and the use and maintenance of firefighting equipment. Not less than one crew (5 employees) shall be trained at smaller operations.
- 12.4.6 Personal Protective Equipment. Protective clothing or equipment shall be worn as specified in Section 5.0.
- 12.4.7 Noise. Permissible noise exposures shall conform to those specified in Section 3.2.
- 12.4.8 Ground Support
 - 12.4.8.1 Tunnel Portal Area. Portals shall be protected and supported where loose soil or rock or fractured material is encountered.
 - 12.4.8.2 Tunnel Area
 - 12.4.8.2.1 The employer shall examine and test the roof, face, and walls of the work area at the start of each shift and frequently thereafter.
 - 12.4.8.2.2 Loose ground shall be removed or supported. Ground conditions along haulage ways and travel ways shall be examined periodically and scaled or supported as necessary.
 - 12.4.8.2.3 Torque meters and torque wrenches shall be available at tunnels where rock bolts are used for ground support. Frequent tests shall be made to determine if bolts meet the required torque. The test frequency shall be determined by rock conditions and distance from vibration sources.

- 12.4.8.2.4 Damaged or dislodged tunnel supports, whether steel sets or timber, shall be repaired or replaced and whenever possible the new supports shall be installed before removing the damage supports.
- 12.4.8.2.5 All sets, including horseshoe-shaped or arched rib steel sets, shall be designed and installed so that the bottoms will have required anchorage to prevent pressures from pushing them inward into the excavation. Lateral bracing shall be provided between sets to further stabilize the support.
- 12.4.8.3 Shafts
- 12.4.8.3.1 Small diameter shafts, which employees are required to enter, shall be provided with a steel casing, concrete pipe, timber, or other material of required strength to support the surrounding earth.
- 12.4.8.3.2 The casing and bracing shall be provided the full depth of the shaft, or at least 1.5 m into solid rock if possible, and shall extend at least 30 cm above ground level and be equipped with a cover that can be locked into position. This cover shall be in place whenever no work is being performed in the excavation and until the excavation is backfilled to ground level.
- 12.4.8.3.3 All wells or shafts over 1.5 m in depth shall be retained with lagging, piling, or casing.
- 12.4.8.3.4 Following blasting operations in shafts, the employer shall inspect the walls, ladders, timbers, blocking, and wedges of the last set to determine if they have loosened. Where found unsafe, corrections shall be made before operations are started.
- 12.4.8.3.5 Safety belts shall be worn on skips and platforms used in shafts by crew when the skip or cage does not occlude the opening to within 30 cm of the sides of the shaft, unless guardrails or cages are provided.
- 12.4.8.3.6 Suspended scaffold machines with cast metal parts shall be prohibited.
- 12.4.8.3.7 Every suspended scaffold shall be tested with twice the maximum loading before being put into operation.
- 12.4.8.3.8 All anchorages of suspended scaffolds shall be inspected at the beginning of each shift.
- 12.4.8.3.9 Each person supported by a suspended scaffold shall be secured by a safety belt and lanyard attached to an independently supported safety line before they get into the scaffold and shall remain so attached until they are completely off the scaffold.
- 12.4.8.3.10 There shall be a safety line for each person. Independent wire ropes at each end of a suspended scaffold, with approved grabbing and locking devices, may be used instead of the safety line.
- 12.4.8.3.11 A tender shall be stationed at the shaft entrance whenever workmen are in the shaft. He will be assigned no other duties.
- 12.4.8.3.12 When dewatering of the shaft is required, a standby pump in operable condition capable of maintaining a dewatered condition will be kept immediately available.

- 12.4.9 Drilling
 - 12.4.9.1 Equipment that is to be used during a shift shall be inspected each shift by a competent person. Equipment defects affecting safety shall be corrected before the equipment is used.
 - 12.4.9.2 The drilling area shall be inspected for hazards before starting the drilling operation.
 - 12.4.9.3 Employees shall not be allowed on a drill mast while the drill bit is in operation.
 - 12.4.9.4 When a drill is being moved from one drilling area to another, drill steel, tools, and other equipment shall be secured, and the mast placed in a safe position.
 - 12.4.9.5 Receptacles or racks shall be provided for drill steel stored on jumbos.
 - 12.4.9.6 Before drilling cycle is started, warning shall be given to men working below jumbo decks.
 - 12.4.9.7 Drills on columns shall be anchored firmly before drilling is started and shall be retightened frequently thereafter.
 - 12.4.9.8 The employer shall provide mechanical means for lifting drills, roof bolts, mine strips, and other unwieldy heavy material to the top decks of jumbos over 3 m in height.
 - 12.4.9.9 The employer shall provide stair access to jumbo decks wide enough to accommodate two persons if the deck is over 3 m in height.
 - 12.4.9.10 On jumbo decks over 3 m in height, guardrails which are removable (pipe in sockets with chain handrail), or equal, shall be provided on all sides and back platforms.
 - 12.4.9.11 Scaling bars shall be in good condition at all times, and blunted and severely worn bars shall not be used.
 - 12.4.9.12 When jumbos are being moved, riders shall not be allowed on the jumbo unless they are assisting the driver.
 - 12.4.9.13 Before commencing the drill cycle, the face and lifters shall be examined for misfires (residual explosives) and, if found, they shall be removed before drilling commences at the face. Lifters shall not be drilled through blasted rock (muck) or water.
 - 12.4.9.14 Air lines that are buried in the invert shall be identified by signs posted nearby, warning all personnel.
- 12.4.10 Blasting. All blasting and explosives-handling operations shall be conducted in compliance with Section 4.4.
- 12.4.11 Haulage
 - 12.4.11.1 Equipment that is to be used during a shift shall be inspected by a competent person each shift. Equipment defects affecting safety shall be corrected before the equipment is used.

- 12.4.11.2 Powered mobile equipment shall be provided with adequate brakes.
- 12.4.11.3 Powered mobile haulage equipment shall be provided with audible warning devices. Lights shall be provided at both ends.
- 12.4.11.4 Cab windows shall be of safety glass, or equivalent, in good condition, and shall be kept clean.
- 12.4.11.5 Backstops or brakes shall be installed on inclined conveyor drive units to prevent conveyors from running in reverse and creating a hazard to employees.
- 12.4.11.6 No employee shall be permitted to ride a power-driven chain , belt, or bucket conveyor, unless the conveyor is specifically designed for the transportation of employees.
- 12.4.11.7 The employer shall not permit employees to ride in dippers, shovel buckets, forks, clamshells, or in the beds of dump trucks, or on haulage equipment not specifically designed or adapted for the transportation of employees. Persons may be raised and lowered in the shaft in a boatwain's chair. Persons hoisted in this manner shall wear a parachute type harness with an independent safety line attached.
- 12.4.11.8 Electrically powered mobile equipment shall not be left unattended unless the master switch is in the off position, all operating controls are in the neutral position, and the brakes are set, or other equivalent precautions are taken against rolling.
- 12.4.11.9 When dumping cars by hand, the car dumps shall be provided with tie-down chains or bumpers blocks to prevent cars from overturning.
- 12.4.11.10 Rocker-bottom or bottom-dump cars shall be equipped with positive locking devices.
- 12.4.11.11 Equipment which is to be hauled shall be so loaded and protected as to prevent sliding or spillage.
- 12.4.11.12 Parked railcars shall be blocked securely.
- 12.4.11.13 Berms, bumper blocks, safety books, or similar means shall be provided to prevent overtravel and overturning at dumping locations.
- 12.4.11.14 Where necessary, bumper blocks, or the equivalent, shall be provided at all track ends.
- 12.4.11.15 Supplies, materials, and tools, other than small hand tools, shall not be transported with employees in mantrip cars.
- 12.4.12 Electrical Equipment
 - 12.4.12.1 Electrical equipment shall conform to the requirements of Section 7.0.
 - 12.4.12.2 Powerlines shall be well separated or insulated from waterlines, telephone lines, and airlines. In underground construction where electrical blasting is used, the blasting line shall always be underground and on the opposite side of the tunnel from the power lines with a minimum of 2 m "lighting" gap.

- 12.4.12.3 Oil-filled transformers shall not be used underground unless they are located in a fireresistant enclosure and surrounded by a dike to contain the contents of the transformers in event of a rupture.
- 12.4.13 Hoisting
 - 12.4.13.1 Hoisting machines, either powered or hand operated, shall be worm-gearred or powered both ways. The design must be such that when the power is stopped, the load cannot move.
 - 12.4.13.2 Controls for powered hoists shall be of the deadman type with a nonlocking switch or control.
 - 12.4.13.3 A device to shut off the power shall be installed a head of the operating control.
 - 12.4.13.4 Hand-operated release mechanisms, which can permit the load to descend faster than the speed rating, shall not be used.
 - 12.4.13.5 Hoist machines with cast metal parts shall not be used.
 - 12.4.13.6 Every hoist shall be tested with twice the maximum load before being put into operation, and annually thereafter.
 - 12.4.13.7 All anchorages of hoists shall be inspected at the beginning of each shift.
 - 12.4.13.8 An enclosed covered metal cage shall be used to raise and lower persons in the shaft. The cage shall be designed with a safety factor of 4 and shall be load-tested prior to use. The exterior of the cage shall be free of projections or sharp corners. Only closed shackles shall be used in the cage rigging.
 - 12.4.13.9 If the cage is equipped with a door, a positive locking device shall be installed to prevent the door from opening accidentally while the cage is being lowered or raised while hoisting or lowering employees.

12.5 Caissons

- 12.5.1 Wherever, in caisson work in which compressed air is used, and the working chamber is less than 3.3 m in length, and when such caissons are at any time suspended or hung while work is in progress so that the bottom of the excavation is more than 2.7 m below the deck of the working chamber, a shield shall be erected therein for the protection of the employees.
- 12.5.2 Shafts shall be subjected to a hydrostatic or air-pressure test, at which pressure they shall be tight. The shaft shall be stamped on the outside shell about 30 cm from each flange to show the pressure to which they have been subjected.
- 12.5.3 Whenever a shaft is used, it shall be provided, where space permits, with a safe, proper, and suitable staircase for its entire length, including landing platforms, not more than 6 m apart. Where this is impractical, suitable ladders shall be installed with landing platforms located 6 m apart to break the climb.
- 12.5.4 All caissons having a diameter or side greater than 3 m shall be provided with a man lock and shaft for the exclusive use of employees.

- 12.5.5 In addition to the pressure gauge in the locks, an accurate pressure gauge shall be maintained on the outer and inner side of each bulkhead. These pressure gauges shall be accessible at all times and kept in accurate working order.
- 12.6 Cofferdams
- 12.6.1 If overtopping of the cofferdam by high waters is possible, means shall be provided for controlled flooding of the work area.
- 12.6.2 Warning signals for evacuation of employees in case of emergency shall be developed and posted.
- 12.6.3 Cofferdam walkways, bridges, or ramps with at least two means of rapid exit shall be provided with guardrails as specification in Section 2.5.
- 12.6.4 Cofferdams located close to navigable shipping channels shall be protected from vessels in transit, where possible.
- 12.6.5 Where men or equipment are required or permitted on cofferdams, walkways, bridges, or ramps with standard guardrails or equivalent protection shall be provided.
- 12.6.6 A plan including warning signal for evacuation of men and equipment in case of emergency and for controlled flooding shall be developed and used.

13. DEMOLITION

13.1 Definitions

Balling. To demolish by the impact of a heavy metal ball swung by the boom of a crane.

Clamming. To demolish or to remove debris by a clam shell attached to a crane.

13.2 Preparatory Operations

- 13.2.1 Prior to permitting employees to start demolition operations, an engineer shall make a survey of the structure to determine the condition of the framing, floors, and walls, and possibility of unplanned collapse of any portion of the structure. Any adjacent structure where employees may be exposed shall also be similarly checked. The employer shall have evidence in writing that such a survey has been performed.
- 13.2.2 When employees are required to work within a structure to be demolished which has been damaged by fire, flood, explosion, or other cause, the walls or floor shall be shored or braced.
- 13.2.3 All electric, gas, water, steam, sewer, and other service lines shall be shut off, capped, or otherwise controlled, outside the building before demolition work is started. In each case, any utility company which is involved shall be notified in advance.

- 13.2.4 If it is necessary to maintain any power, water or other utilities during demolition, such lines shall be temporarily relocated and protected.
- 13.2.5 It shall be determined if any type of hazardous chemicals, gases, explosives, flammable materials, or similarly dangerous substances have been used in any pipes, tanks, or other equipment on the property. When the presence of any such substances is apparent or suspected, testing and purging shall be performed and the hazard eliminated before demolition is started.
- 13.2.6 Where hazard exists to employees falling through wall openings, the opening shall be protected with a guardrail to a height of approximately 1 m.
- 13.2.7 When debris is dropped through holes in the floor without the use of chutes, the area onto which the material is dropped shall be completely enclosed with barricades not less than 1 m high and not less than 1.8 m back from the projected edge of the opening. Signs, warning of the hazard of falling materials, shall be posted at each level. Removal shall not be permitted in this lower area until debris handling above ceases.
- 13.2.8 All floor openings, not used as material drops, shall be covered with wooden planks to support the weight of any load which may be imposed. Such planks shall be secured to prevent its accidental movement.
- 13.2.9 Except for the cutting of holes in floors for chutes, holes through which to drop materials, preparation of storage space, and similar necessary preparatory work, the demolition of exterior walls and floor construction shall begin at the top of the structure and proceed downward. Each story of exterior wall and floor construction shall be removed and dropped into the storage space before commencing the removal of exterior walls and floors in the story next below.
- 13.2.10 Employee entrances to multi-story structures being demolished shall be completely protected by sidewalk sheds or canopies, or both, providing protection from the face of the building for a minimum of 2.5 m. All such canopies shall be at least 60 cm wider than the building entrances or openings (30 cm wider on each side thereof), and shall be capable of sustaining a load of 0.7 kg/sq cm.
- 13.3 Stairs, Passageways, and Ladders**
- 13.3.1 Only those stairways, passageways, and ladders, designated as means of access to the structure of a building, shall be used. Other access ways shall be entirely closed at all times.
- 13.3.2 All stairs, passageways, ladders and incidental equipment shall be periodically inspected and maintained in a clean safe condition.
- 13.3.3 In a multistory building, when a stairwell is being used, it shall be properly illuminated by either natural or artificial means and completely covered over at a point not less than 2 floors below the floor on which work is being performed. Access to the floor where the work is in progress shall be through a properly lighted, protected and separate passageway.

13.4 Chutes

- 13.4.1 No material shall be dropped to any point lying outside the exterior walls of the structure unless the area is effectively protected.
- 13.4.2 All materials chutes or sections thereof, at any angle of more than 45 degrees from the horizontal, shall be entirely enclosed, except for openings equipped with closures at or about floor level for the insertion of materials. The openings shall not exceed 1.2 m in height measured along the wall of the chute. At all stories below the top floor, such openings shall be kept closed when not in use.
- 13.4.3 A gate shall be installed in each chute at or near the discharge end. A competent employee shall be assigned to control the operation of the gate and the backing and loading of trucks.
- 13.4.4 When operations are not in progress the area surrounding the discharge end of a chute shall be securely closed.
- 13.4.5 Any chute opening, into which workmen dump debris, shall be protected by a guardrail approximately 1 m above the floor or other surface on which the men stand to dump the material. Any space between the chute and the edge of openings in the floors through which it passes shall be covered over.
- 13.4.6 Where the material is dumped from mechanical equipment or wheelbarrows, a securely attached toeboard or bumper, not less than 10 cm thick and 15 cm high, shall be provided at each chute opening.
- 13.4.7 Chutes shall be designed and constructed of such strength as to eliminate failure caused by impact of materials or debris loaded therein.
- 13.5 Removal of Materials Through Floor Openings. Any openings cut in a floor for the disposal of materials shall be no larger in size than 25 percent of the aggregate of the total floor area, unless the lateral supports of the removed flooring remain in place. Floors weakened or otherwise made unsafe by demolition operations shall be shored to carry safely the intended imposed load from demolition operations.

13.6 Removal of Walls, Masonry Sections and Chimneys

- 13.6.1 Masonry walls, or other sections of masonry, shall not be permitted to fall upon the floors of the building in such masses as to exceed the safe carrying capacities of the floors.
- 13.6.2 No wall section which is more than 1 story in height shall be permitted to stand alone without lateral bracing, unless such wall was originally designed and constructed to stand without such lateral support and is in a condition safe enough to be self-supporting. All walls shall be left in a stable condition at the end of each shift.
- 13.6.3 Employees shall not be permitted to work on the top of a wall when weather conditions constitute a hazard.
- 13.6.4 Structural or load-supporting members on any floor shall not be cut or removed until all stories above such a floor have been demolished and removed. This

provision shall not prohibit the cutting of floor beams for the disposal of materials or for the installation of equipment, provided that the requirements of Sections 13.5 and 13.7 are met.

- 13.6.5 Floor openings within 3 m of any wall being demolished shall be planked solid. except when employees are kept out of the area below.
- 13.6.6 In buildings of “skeleton-steel” construction, the steel framing may be left in place during the demolition of masonry. Where this is done. all steel beams, girders and similar structural supports shall be cleared of all loose material as the masonry demolition progresses downward.
- 13.6.7 Walkways or ladders shall be provided to enable employees to safely reach or leave any scaffold or wall.
- 13.6.8 walls, which serve as retaining walls to support earth or adjoining structures, shall not be demolished until such earth has been properly braced or adjoining structures have been properly underpinned.
- 13.6.9 Walls, which are to serve as retaining walls against which debris will be piled, shall be capable of safely supporting the imposed load.

13.7 manual Removal of Floors

- 13.7.1 openings cut in a floor shall extend the full span of the arch between supports.
- 13.7.2 Before demolishing any floor arch, debris and other material shall be removed from such arch and other adjacent floor area. Planks not less than 5 cm by 25 cm in cross section, full size undressed, shall be provided and shall be used by employees to stand on while removing floor arches between beams. Such planks shall be so located as to provide a safe support for the workmen should the arch between the beams collapse. The open space between planks shall not exceed 40 mm.
- 13.7.3 Safe walkways, not less than 46 cm wide, formed of planks not less than 5 cm thick if wood or of equivalent strength if metal, shall be provided and used by workmen when necessary to enable them to reach any point without walking upon exposed beams.
- 13.7.4 Stringers of ample strength shall be installed to support the flooring planks, and the ends of such stringers shall be supported by floor beams or girders, and not by floor arches alone.
- 13.7.5 Planks shall be laid together over solid bearings with the ends overlapping at least 30 cm.
- 13.7.6 When floor arches are being removed, employees shall not be allowed in the area directly underneath, and such an area shall be barricaded to prevent access to it.
- 13.7.7 Demolition of floor arches shall not be started until they and the surrounding floor area for a distance of 6 m have been cleared of debris and any other unnecessary materials.

13.8 Removal of Walls, Floors, and Materials with Equipment

- 13.8.1 Mechanical equipment shall not be used on floors or working surfaces unless such floors or surfaces are of sufficient strength to support the imposed load.
- 13.8.2 Floor openings shall have curbs or stoplogs to prevent equipment from running over the edge.

13.9 Storage

- 13.9.1 The storage of waste material and debris on any floor shall not exceed the allowable floor loads.
- 13.9.2 In buildings having wooden floor construction, the flooring boards may be removed from not more than 1 floor above grade to provide storage space for debris, provided falling material is not permitted to endanger the stability of the structure.
- 13.9.3 When wood floor beams serve to brace interior walls of free-standing exterior walls, such beams shall be left in place until other equivalent support can be installed to replace them.
- 13.9.4 Floor arches, to an elevation of not more than 7.6 m above grade, may be removed to provide storage area for debris provided, that such removal does not endanger the stability of the structure.
- 13.9.5 Storage space into which material is dumped shall be blocked off, except for openings necessary for the removal of material. Such openings shall be kept closed at all times when material is not being removed.

13.10 Removal of Steel Construction

- 13.10.1 When floor arches have been removed, planking in accordance with paragraph 13.7.2 shall be provided for the workers engaged in razing the steel framing.
- 13.10.2 Cranes, derricks, and other hoisting equipment used shall meet the requirements specified in Section 6.3.
- 13.10.3 Steel construction shall be dismantled column length by column length, and tier by tier (columns may be in 2-story lengths).
- 13.10.4 Any structural member being removed shall not be overstressed.

13.11 Mechanical Demolition

- 13.11.1 No workers shall be permitted in any area, which can be adversely affected by demolition operations, when balling or clamming is being performed. Only those workers necessary for the performance of the operations shall be permitted in this area at any time.
- 13.11.2 The weight of the demolition ball shall not exceed 50 percent of the crane's rated load, based on the length of the boom and the maximum angle of operation at which the demolition ball will be used, or it shall not exceed 25 percent of the nominal breaking strength of the line by which it is suspended, whichever results in a lesser value.

- 13.11.3 The crane boom and loadline shall be as short as possible.
- 13.11.4 The ball shall be attached to the loadline with a swivel-type connection to prevent twisting of the loadline, and shall be attached by positive means in such a manner that the weight cannot become accidentally disconnected.
- 13.11.5 When pulling over walls or portions thereof, all steel members affected shall have been previously cut free.
- 13.11.6 All roof cornices or other such ornamental stonework shall be removed prior to pulling walls over.
- 13.11.7 During demolition, continuing inspections by a competent person shall be made as the work progresses to detect hazards resulting from weakened or deteriorated floors, or walls, or loosened material. No employee shall be permitted to work where such hazards exist until they are corrected by shoring, bracing, or other effective means.
- 13.12 Selective Demolition by Explosives. Selective demolition by explosives shall be conducted in accordance with the applicable sections of Section 4.4.

14. MATERIAL STORAGE AND HANDLING

- 14.1 Definitions. No specific definitions required.
- 14.2 **General**
 - 14.2.1 All materials stored in tiers shall be stacked, racked, blocked, interlocked, or otherwise secured to prevent sliding, falling, or collapse.
 - 14.2.2 Maximum safe load limits of floors within buildings and structures, in kg/sq cm shall be conspicuously posted in all storage areas, except for floor or slab on grade. Maximum safe loads shall not be exceeded.
 - 14.2.3 Aisles and passageways shall be kept to provide for the free and safe movement of material handling equipment or employees. Such areas shall be kept in good repair.
 - 14.2.4 material shall be stacked as low as practical and in no case higher than 6 m.
 - 14.2.5 Unauthorized persons shall be prohibited from entering storage areas.
 - 14.2.6 Material stored inside buildings under construction shall not be placed within 2 m of any hoistway or inside floor openings, nor within 3 m of an exterior wall which does not extend above the top of the material stored.
 - 14.2.7 Employees required to work on stored material in silos, hoppers, tanks, and similar storage areas shall be equipped with lifelines and safety belts meeting the requirements of Section 5.8.
 - 14.2.8 Non-compatible materials shall be segregated in storage.
 - 14.2.9 Bagged materials shall be stacked by stepping back the layers and crosskeying the bags at least every 10 bags high.

- 14.2.10 Materials shall not be stored on scaffolds or runways in excess of supplies needed for immediate operations.
- 14.2.11 Flammable liquids and greases in a storage building shall be in a No Smoking area and separated from combustible construction and other stored materials by 15 m.
- 14.2.12 Metal strapping and wires shall be cut only with a cutter which securely grips the strap or wire on both sides of the cut.
- 14.2.13 Employees shall not work or pass under elevated work areas unless protected by overhead protection.
- 14.2.14 A clearance of 60 cm shall be maintained around the path of travel of fire doors unless a barricade is provided. Material shall not be stored within 90 cm of a fire door opening.
- 14.2.15 Where the movement of materials may be hazardous to employees, taglines or other suitable devices shall be used to control the loads being handled by hoisting equipment. They shall be of a nonconductive type when used near energized lines.
- 14.2.16 The hoist rope shall not be wrapped around the load. This requirement shall not apply to electric construction crews when setting or removing poles.
- 14.2.17 When moving equipment under or near energized lines, a designated employee shall be utilized to determine that required clearance is maintained.
- 14.3 **Lumber**
- 14.3.1 Used lumber shall have all nails withdrawn before stacking.
- 14.3.2 Lumber shall be stacked on level and solidly supported sills.
- 14.3.3 Lumber shall be so stacked as to be stable and self-supporting.
- 14.3.4 Lumber to be handled manually shall not be stacked more than 4.8 m high.
- 14.4 **Cement and Lime**
- 14.4.1 Bags of cement and lime shall not be stacked more than 10 bags high without setback, except when restrained by walls of appropriate strength.
- 14.4.2 The bags around the outside of the stack shall be placed with the mouths of the bags facing the center of the stack.
- 14.4.3 During unstacking, the entire top of the stack shall be kept nearly level and the necessary setback maintained.
- 14.5 **Brick**
- 14.5.1 Brick stacks shall not be more than 2 m in height. When a loose brick stack reaches a height of 1.2 m it shall be tapered back 15 cm in every meter of height above the 1.2 m level.
- 14.5.2 Brick shall be stacked on an even, solid surface.
- 14.5.3 Unitized brick shall not be stacked more than 3 units in heights.

14.6 Blocks

- 14.6.1 Blocks shall be stacked in tiers on solid, level surfaces,
- 14.6.2 When masonry blocks are stacked higher than 2 m, the stack shall be tapered back one-half block per tier above the 2 m level.

14.7 Reinforcing and Structural Steel

- 14.7.1 Reinforcing steel shall be stored in orderly piles away from walkways and roadways.
- 14.7.2 Structural steel shall be securely piled to prevent members sliding off or the pile toppling over.

14.8 Cylindrical Material

- 14.8.1 Pipe, structural steel, poles, bar stock, round wood pilings and other cylindrical materials, unless racked, shall be stacked in an orderly manner on preferably a solid, level surface and shall be blocked to prevent spreading, rolling, or tilting. Separate stacks shall be made for each size.
- 14.8.2 Pipe, unless racked, shall not be stacked higher than 1.5 m.
- 14.8.3 Either a pyramided stack or battened stack shall be used. Where a battened type of stack is used, the outside pile or pole shall be securely chocked.
- 14.8.4 Battened stacks shall be tapered back at least one pile or pole in each tier.
- 14.8.5 Unloading of round material shall be done so that no person is required to be on the unloading side of the carrier after the tie wires have been cut or during the unloading of the stacks.

14.9 Sand, Gravel and Crushed Stone

- 14.9.1 in withdrawing sand, gravel, and crushed stone from stockpiles, no overhanging or vertical face shall exist at any time.
- 14.9.2 Material dumped against walls or partitions shall not be stored to a height that will endanger the stability or exceed the resisting strength of such walls and partitions.

14.10 Housekeeping

- 14.10.1 Loose or light material shall not be stored or left on roofs or floors that are not closed in, unless it is safely secured.
- 14.10.2 The storage area shall be kept from the accumulation of unnecessary combustible materials. Weeds and grass shall be kept down and a regular procedure provided for the periodic clean up of the entire area.
- 14.10.3 Rubbish, brush, long grass, or other combustible material shall be kept from areas where flammable and combustible liquids are stored, handled or processed.
- 14.11 Drainage. For protection of inside stored materials floor drainage system shall be provided, adequate to accept wash-down water. For outside storage the design shall be based on a minimum rainfall rate of 10 cm/hr.